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THE

WORKS

OF

FRANCIS BACON,

BARON VERULAM, VISCOUNT ST. ALBAN, AND LORD HIGH CHANCELLOR OF ENGLAND.

VOLUME THE TWELFTH

CONTAINING

THE HISTORY OF WINDS,

THE HISTORY OF CONDENSATIONS AND RARIFACTIONS,

AND PHYSICAL ESSAYS.

LONDON:

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PREFACE.

*THE following History of Winds, has scarce been more improved by the moderns, than the preceding History of Life and Death. It should seem as if few entered into the nature and design of these pieces; so as to perceive how far they are carried; and how they may be farther advanced: and yet the author appears to have given ample directions for the purpose. For though he has himself gone great lengths in these particular histories; yet they are rather intended as larger examples, to teach mankind the method of enquiring; than aim at being complete enquiries themselves.**

* No author has with greater diligence and exactness, I will not say enquired into, as taught others the way of enquiring into this subject, than the great Lord Verulam, in his History of Winds. And though he there writes historically in many particulars, I cannot determine whether they may be safely relied on. That man had a vast and most extensive genius; equal, in my opinion, to the full discovery of all nature; had he not been prevented by civil affairs.

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Numerous observations have been made, and journals kept of the wind and the weather: but even complete sets of such observations will afford little instructions; unless they are regularly tabled, and offered to the mind in some tolerable order. Perhaps it would not be amiss, if all the observations of this kind were ranged under the following heads; or, if these be insufficient, under others of the same general kind; that their doctrine might be drawn out, and a better acquaintance cultivated with the subject. This would be making that use of the present history which the author encourages, and plainly intended.

Yet, notwithstanding his post, and employments, he has set on foot such a method of enquiries as opens the widest field to the labours of others. His single History of Winds sufficiently demonstrates his incredible capacity and diligence; by the clue and direction whereof, infinite remarks and observations may be made, appertaining to this subject. Morhof. in Polyhist. Tom. II. Cap. 23. de Meteoris Aereis, præcipue de Ventis, page 381.

INTRODUCTION.

THE Winds may be called the wings of mankind; by means whereof men fly through the sea, and maintain traffic and correspondence with all the parts of the globe. They are also the sweepers of man's habitation, the earth; and at the same time brush and cleanse the air about it. On the other hand, they sometimes tear up and enrage the sea, that would otherwise remain quiet or undestructive; and have likewise other mischievous effects. Again, they produce strong and violent motions, without human assistance; and thus, as servants to mankind, drive our ships, and turn our mills. They might also be applied to abundance of other useful purposes; if men would exert their diligence. The nature of the winds is usually reckoned an occult and secret thing; and no wonder, whilst the nature and power of the air, which the winds administer to and wait upon; (as in the language of the poets, Æolus does on Juno) remain absolutely unknown. They are not primary creatures, or of the first six days works, as to their action; no more than the other meteors; but were produced later in the order of creation.

A

DRAUGHT

FOR THE PARTICULAR HISTORY

OF THE

WIND, &c.

SECT. I.

THE TABLE OF ENQUIRY: OR A SET OF HEADS FOR THE PARTICULAR HISTORY OF THE WIND: WITH THE CONDUCT TO BE OBSERVED IN THE PROSECUTION.

The Names of the Winds.

UNDER this title class the winds, with regard to the points of the compass, or the method observed at sea; and assign them their several names, ancient or modern; so as to denote them fixedly and invariably.

Winds are either 1. general, 2. stated, 3. serving*, or 4. free. We call those general winds,

See this term explained under Sect. v.

which never cease to blow; those stated winds, which blow only at certain times; those serving winds, which blow oftenest; and those free winds, which blow indifferently at all times.

General Winds.

Enquire whether there be any general winds, and genuine motions of the air itself; and if there be, in what series of motion, and in what places they blow.

Stated Winds.

Enquire what winds are annual, and periodical, and in what countries; and whether there be any winds so precisely stated, as to return regularly at certain days and hours, like the tide of the sea.

Serving Winds.

Enquire what winds are waiting and familiar, or most constant to what countries; at what times they blow in those countries: which in the spring; which in the summer; which in the autumn; which in the winter; which are equinoctial; which solstitial; which blow in the morning; which at noon: which in the evening; and which at night.

Again, enquire which are sea-winds; and which blow from the continent: and exactly ob-

serve the differences between the sea and land-winds; as well those that blow upon, as those that blow from the land and sea.

Free Winds.

Enquire whether winds do not blow from all points of the heavens.

Winds do not differ much more in the quarters they blow from, than in their qualities; some being strong, others gentle; some constant, others variable; some cold, others hot; some moist, and dissolving, others dry, and constringing; some bringing clouds, rain, or storms; others calming and clearing the air.

The different qualities of winds.

Enquire into and give the history of the several species, or above mentioned differences of winds; and how they vary as to climates and countries.

There are three local origins of winds; as being either, 1. precipitated from above; 2. rising out of the earth*: produced in the body of the air itself.

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* And sea.

The local origins of winds.

Enquire after the three abovementioned origins of winds; viz. 1. Which of them descend from that called the middle region of the air; 2. Which breathe from the caverns of the earth; whether they rush out boisterous, and in a body; or escape insensibly by degrees, and afterwards roll together, as rivulets collect into rivers; 3. and lastly, which of them are generated indifferently, in all places, from the swelling and expanding of the contiguous air.

But all the productions of winds are not original; some being accidental, and proceeding from a compression, percussion, and repercussion of the air.

Accidental generations, or productions of winds.

Let enquiry be made into all the accidental generations of winds: though these are not proper generations of winds; but rather increase and strengthen them, than actually produce and excite them.

And so much for the winds that commonly obtain. But besides these there are also certain extraordinary winds, out of the common course; such as fiery winds, whirlwinds, stormy winds, and tornados; and these rage above ground:

there are likewise subterraneous winds; some whereof are vaporous, sultry, and mercurial: as in mines: others sulphureous and burst out of chasms, caused by earthquakes; or rise hot from burning mountains.

Extraordinary winds, and sudden gusts.

Enquire into all uncommon, monstrous and miraculous kinds of winds.

From the particular kinds of winds, let the enquiry pass on to the things which contribute to them; or are supposed to raise or lay them.

The things that contribute to winds; and excite or appease them.

The enquiry should not run out into astrological considerations about the winds; nor accuracies as to the horoscope of the heavens: only the more manifest observations of the winds increasing at the rising of certain stars, or the eclipsing of the luminaries, or the conjunctions of the planets, are not to be neglected: and remark how far they depend upon the course of the sun or moon.

Enquire what the different kinds of meteors contribute to the winds; what earthquakes contribute; what showers; and what the meeting of

winds together: for these things hang in a chain, and draw in each other.

Enquire what a diversity of vapours and exhalations contributes to the winds; and which kinds of them are the more productive of winds; and how far the nature of winds depends upon these their materials.

Enquire what those things contribute or make to winds, which are found upon the earth; what the mountains contribute, and the dissolving of snow upon their tops; what those huge masses of ice which float, and are carried about in the sea; what the difference of soil, or any large tracts of land, as marshes, sands, woods, champaigns, &c. Again, enquire what those things contribute which are performed by human agency; as the burning of heath, fuzzes, &c. for the improvement of land; the burning of corn, or villages, as in wars; the draining of marshy lands; the continual discharging of cannon; the ringing of numerous bells together as in great cities, &c. It is true, these are smaller matters; but they may have some effect.

Enquire into all the ways of raising and laying the winds; though sparingly as to any of the fabulous or superstitious methods of doing it.

From hence let the enquiry pass on to the limitations of the winds, in height, extension, and duration.

The limitations of the winds.

Let diligent enquiry be made as to the height, or elevation, of the winds; and if there be any tops of mountains where the winds blow not; or if the clouds sometimes appear motionless and stationary, at the same time that the winds are blowing strong upon the earth.

Enquire carefully into the space which the winds are found at once to possess; and within what bounds they keep. For example, suppose the south wind should blow in a certain place; enquire whether the north wind actually blow at the same time, ten miles from that place. And again, enquire into how narrow a compass the winds may be reduced, whilst they run, as it were, through pipes; which they seem to do in some kinds of whirlwinds.

Enquire how long winds usually continue in their greatest, mean, or smallest duration, before they slacken, and as it were expire again; in what manner they rise and begin; and in what manner they languish and cease; whether of a sudden, by degrees, or how.

From these limits of the winds, let the enquiry proceed to their successions; either among themselves, or with regard to rain and showers: for as all winds and rain lead up each other, it would be a pleasure to know what order they dance in.

The successions of the winds.

Enquire whether there be any rule, or certain observation, as to the order in which the winds succeed one another; and whether it be conformable to the sun's motion, or otherwise; and however it be, to discover the fact.

Enquire concerning the succession and interchance of winds and rain: since it is usual for rain to allay the winds; and for the winds to keep up and dissipate rain.

Observe whether the succession of the winds is renewed after a certain period of years; and, if so, to find what that period is.

From the order of succession, let the enquiry glide on to the motions of the winds. The motions of the winds branch themselves into seven distinct enquiries; three whereof are contained in the preceding articles; and four remain hitherto untouched: for we have already mentioned, 1. That motion of them, which regards the points of the compass they blow from. 2. Their motion in the three lines of direction, upwards, downwards, and sidewise. 3. Their accidental motion by compression; so that there remains, 4. Their progressive motion. 5. Their undulatory motion. 6. Their impinging motion. And, 7. Their motion in organs, and machines of human invention.

Different motions of the winds.

As progression always begins from a certain point; let a very careful enquiry be made into the place of the primary rise, or, as it were, first fountain of the winds: for winds resemble fame; and though they tumultuate and bluster every where, yet hide their heads among the clouds. Again, enquire into their progress itself: for example, if a strong north wind blew, upon a certain day and hour, at York; suppose it should, two days afterwards be found to blow at London, &c.

The enquiry into the undulation of the winds must not be omitted. We call that motion the undulation of the winds, wherein a wind, for a small space, increases and slackens, or swells and falls again, like the waves of the sea; the reciprocation whereof is known from the sound they make in buildings. And the differences of this undulation, or rising and falling, betwixt the air and water, must be the more carefully observed; because the air and winds have not that great motion of gravity, which is the chief cause of the undulation in waters.

Let the enquiry be carefully pursued, with regard to the impinging, or meeting of strong winds together; and blowing at the same time: as first, whether many original winds may blow, and dash

against one another at once; and, if this happen, what reciprocation it causes in the motion: and again, what condensations and alterations it produces in the body of the air.

Enquire whether some winds do not blow at the same time above, that others blow below: for clouds have been sometimes observed to move in a contrary direction to that of the weather-cock; and sometimes to be driven briskly, whilst there was a perfect calm near the surface of the earth.

Let a very exact, careful, and particular description be made of the motion of the winds in the sailing of ships.

Describe the motion of the winds in the sails of wind-mills, the flight of hawks, and other birds; and even in the common phænomena and diversions; as the hoisting of flags and streamers; the flying of paper-kites; fighting of battles by the wind, &c. And now, from the motions, let the enquiry pass on to the force and powers of the winds.

The powers of the Winds.

Enquire what effects the winds may have upon the tides and currents; as to keeping them out, driving them in, and causing them to overflow.

Enquire their effect upon vegetables and in-

sects; as to their bringing in of locusts, canker-worms, mill-dews, blights, blasts, &c.*

Enquire their effects, as to purging and infecting the air; the producing of pestilences, diseases, and disorders in animals.

Enquire into their manner of conveying those called spiritual species; as sounds, emissions, light,† &c.

From these powers of the winds, let the enquiry descend to the prognostics of winds; not only for the use of predictions, but on account of their leading up to causes: for prognostics either discover the preparation of things, before they come into action; or their beginnings, before they become manifest to the senses.

Presages or prognostics of Winds.

Let great diligence be used to collect all the kinds of prognostications of winds, except those of an astrological nature; with regard to which we have above laid down our directions: otherwise they may be derived from meteors, waters, the instinct of animals, and many other things.

Lastly, let the whole enquiry be closed by

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* Viz. the scattering abroad, and sowing the seeds of vegetables; in different places, &c.

† See Dr. Derham's paper upon the Motion of Sounds, in the Philosophical Transactions.

searching into methods of imitating the winds, for natural as well as artificial purposes.

Imitations of Winds.

Enquire into the imitations of winds in natural subjects; such are the flatulencies in animal bodies; and the puffings, or displosions of subjects in chemical distillations.

To conclude; let enquiry be made into factitious and artificial winds, gales, and fannings; as by bellows, refrigeratories, or cool-rooms, &c.

Such are the heads requisite to a particular history of the winds; but we expect not that our present stock of experience should be able to answer them all. However, as in trials at law, a good lawyer knows how to put such questions as the case requires; but knows not what the witnesses will answer: so we can proceed no otherwise in the grand cause betwixt nature and mankind; and must leave posterity to see the issue.*

* These articles are not fully spoke to in the following enquiry; and indeed the whole, however great in itself, should be esteemed as little more than the out-lines of a natural history of the wind; that wants to be filled up by future labour, experiments, and observations.

SECT. II.

THE HISTORY OF THE APPELLATIONS OF THE WINDS; ASSIGNING TO EACH A PROPER, FIXED, AND DETERMINATE NAME; IN PROSECUTION OF THE FIRST ARTICLE OF THE TABLE OF ENQUIRY.

For the sake of clearness, and to help the memory, we would enumerate and range the winds, rather according to their natural order and degrees, than under the names and method assigned them by antiquity. We shall, however, annex their ancient names, that the ancient authors from whom we have borrowed many particulars (though without trusting to them) may be the readier consulted.

And for the general division of the winds; let those be termed, 1. cardinal winds, which blow from the four quarters, or cardinal points of the world; those, 2. semi-cardinal, which blow in the middle between the former; and those, 3. median, which blow any where betwixt the others: but of these median winds, let those be called, 4. the greater medians, that blow in the quarters; and all the rest be termed, 5. the lesser median winds.*

* See Varenii Geographia, Cap. 20. and 21.

The particular division of the winds is expressed by the following table.

A TABLE SHEWING THE PARTICULAR DIVISIONS OF THE WINDS; WITH REGARD TO THE MARINER'S COMPASS.

I.

NORTH - - - -	A cardinal point.
North and by east -	The north wind one point to the east.
North-north east - -	The north wind two points to the east. A greater median wind; anciently called Aquilo.
North-east and by north	The north wind three points to the east; anciently called Meses.
North-east - - -	A semi-cardinal wind; or north four points to the east.
North-east and by east	Or, north five points to the east.
East-north-east - -	Or, north six points to the east. A greater median wind; anciently called Cœcias.

East and by north -	Or, north seven points to the east.

II.

EAST - - - - -	A cardinal wind; anciently called Subsolanus.
East and by south -	Or, east one point to the south.
East-south-east - -	Or, east two points to the south. A greater median wind; anciently called Vulturnus.
South-east and by east	Or, east three points to the south.
South-east - - - -	A semi-cardinal wind. Or, east four points to the south.
South-east and by south	Or, east five points to the south.
South-south-east - -	Or, east six points to the south. A greater median wind; anciently called Phænicias.
South and by east -	Or, east seven points to the south.

III.

SOUTH - - - -	A cardinal wind; anciently called Notus or Auster.
South and by west -	Or, south one point to the west.
South-south-west - -	Or, south two points to the west. A greater median wind; anciently called Libonotus.
South-west and by south	Or, south three points to the west.
South-west - - - -	Or, south four points to the west. A semi-cardinal wind; anciently called Libs.
South-west and by west	Or, south five points to the west.
West-south-west - -	Or, south six points to the west. A greater median wind; anciently called Africus.
West and by south -	Or, south seven points to the west.

IV.

WEST - - - - -	A cardinal wind, anciently called Favonius.
West and by north -	Or, west one point to the north.
West-north-west - -	A greater median wind. Or, west two points to the north; and anciently called Corus.
North-west and by west	Or, west three points to the north.
North-west - - -	A semi-cardinal wind. Or, west four points to the north.
North-west and by North	Or, west five points to the north; and anciently called Thrascias.
North-north-west - -	Or, west six points to the north. A greater median wind; anciently called Circius.
North and by west -	Or, west seven points to the north.

There are, besides these, other ancient names of winds; as Apeliotes, Argestes, Olympias, Sciron, Hellespontius, Iapyx, &c. but we pay little regard to them; it is sufficient to have given fixed appellations to the several winds in the regular order and division of the horizon: for we lay no stress upon the understanding of authors; as authors contain but very little to our purpose.

SECT. III.

OF FREE AND GENERAL WINDS; WITH REGARD TO THE SECOND AND FIFTH ARTICLES OF THE TABLE OF ENQUIRY.

THERE is no point of the heavens, but a wind may blow from it; so that if the heavens were divided into as many points as there are degrees in the horizon, there will, one time or other, be found winds blowing from each.*

There are some whole countries where it never rains, or at most very seldom; but none where the winds do not blow; and that frequently.

There are few phænomena observed of general

* That is, supposing, for example, the horizon divided into 360 degrees; as all circles are by mathematicians.

winds; and no wonder, as these winds are principally found within the tropics, where chiefly lie the places, condemned by the ancients for uninhabitable. But those who sail in the open sea, between the tropics, observe a wind, or breeze, continually blowing from east to west; which is not so gentle, but that partly by its own motion, and partly by affecting the current of the sea, it renders it impossible for ships to return towards Peru, the same way they came.

In our European seas, there is observed (when the heavens are clear and serene, and no particular winds stirring) a certain gentle breeze, breathing from the east, and following the sun.

It is found by common observation, that the higher clouds generally move from east to west; and this even at the same time when there is calm, or a wind blowing in a contrary direction, near the surface of the earth. And if this prove not always the case, the reason may be owing to particular winds, sometimes blowing above; so as to disturb, or over-power this general wind.

ADMONITION.

If there be any such general wind, proceeding from the order of the motion of the heavens, it is not strong enough to resist the particular winds. And such a wind becomes more mani-

fest within the tropics, by reason of the larger circles it there has to move in; and also high up, for the same reason; and to enjoy the freer course. Therefore, whoever would endeavour to discover this wind without the tropics, and near the earth's surface (where it breathes but small and soft) let him make the experiment in the open and free air, in the greatest calms, and highest places; and that with a very moveable body; and towards the evening; because at this time the particular east wind blows less.

PRECEPT.

Let a careful observation be made of the weather cock, vanes, streamers, and the like, on the tops of steeples, high edifices, ships, &c. in order to determine whether, in the greatest calms, they do not always tend to the west.

INDIRECT PHÆNOMENA.

It is matter of observation, that the east wind in Europe is a sharp and drying wind; but the west wind, on the contrary, moist and favourable. Does not this proceed from hence, that, upon a supposition of the air's motion from east to west, the east wind, which goes also in that direction, necessarily rarifies, and drives the air before it, so as to make it more dry and preda-

tory; whereas the west wind, which moves in a contrary direction, condenses, and turns the air back upon itself; from whence it becomes less sharp or cutting, and afterwards moistening?

Consult the enquiry of the motion of the tides,* to discover whether the waters move from east to west: for if the heavens, and the waters, which are the extremities of the air, have this motion; it is highly probable that the air itself, which lies between them, participates of it likewise.

ADMONITIONS.

The two preceding phænomena we call indirect; as not pointing out the thing immediately, but consequentially: and this is a kind of phænomena which we willingly admit and receive; in defect of a sufficient stock of direct ones.

It is a certain fact, that there blows a constant, manifest breeze between the tropics; but the cause thereof is doubtful. It may be owing to this; that the air, as we before observed, moves in the direction of the heavens; but less perceptibly without the tropics, because of the smaller circles there. Another reason may be this; that all air is expanded by heat; and, by this

* See the Novum Organum, Part II.

expansion, the contiguous air is of necessity impelled, so as to create that constant breeze; whilst the sun holds on its course: but this expansion must be more considerable within the tropics, where the sun is hottest; and again, but small without them, where it is colder. It might seem a crucial instance* for solving this difficulty, were it but known, whether this breeze continues by night, or not; because the rotation of the air continues by night, though the heat of the sun does not.

Now it is certain this breeze comes not in the night; but in the morning, or some time after the sun is up. Yet this instance does not determine the point; because the nocturnal condensation of the air, especially in such places where the day and night are as different in heat and coldness, as they are equal in their lengths, may check and confound this natural but gentle motion.†

If the air participate of the motion of the heavens; it follows, not only that the east wind coincides with, whilst the west wind opposes, the motion of the air; but also, that the north wind blows, as it were from above; and the south wind as from below, in our hemisphere;

* See Novum Organum, Part II. Aph. XXXVI.

† See the appendix to Dr. Jurin's edition of Varenius.

where the south pole is depressed, and the north pole elevated above the horizon. And this observation was made by the ancients, though with uncertainty and obscurity: but it excellently agrees with modern experience; because the constant breeze we speak of, which may be a motion of the air, is not due east, but north-easterly.*

SECT. IV.

OF STATED WINDS WITH REGARD TO THE THIRD ARTICLE OF THE TABLE OF ENQUIRY.

TRANSITION.

As the minds of men seem to have been dark in the enquiry about general winds; so, in that of stated winds they seem to have been giddy: for of the former they say nothing; and of the latter they talk very ramblingly. But this is the more pardonable, because the thing itself is variable; since stated winds change with the place, so as not to blow the same, for instance, in Egypt, Greece, and Italy.

* Some additions might be made to this section, from Mr. Bohun's Discourse concerning the Origin and Properties of Winds. Printed at Oxford, An. 1671.

That there are stated winds in some place or other, may appear from the very name; and again, from that other appellation of Etesian, or anniversary winds.

One cause of the overflowing of the Nile, was antiently made the blowing of the Etesian, or northerly winds, at that time of the year; so as to prevent the course of the river into the sea, and drive it backwards.

There are currents found in the sea, which can neither be attributed to the natural motion of the ocean, nor to the declivity of more elevated parts, nor to the straitness of opposite shores, nor to promontories running out into the sea; but are plainly governed by stated winds.

Those who will not allow Columbus to have conceived so certain and fixed an opinion of the West-Indies, from the relation of a Spanish pilot, yet think it trifling for him to have formed it upon the obscure traces and rumours of antiquity, pretend he conjectured there must be a continent to the west, from the stated winds on the coast of Portugal. And though this be an uncertain and somewhat improbable thing; since the course of those winds can scarce be kept for so great a distance; yet it derives honour to the present enquiry, if the discovery of a new world be owing to one axiom, or observation, of the many it contains.

Wherever there are high mountains covered with snow; stated winds blow from that quarter at the time the snow dissolves.

We suspect also, that stated winds may blow from great tracts of marsh-land, overflowed in the winter; and this about such time as the sun begins to dry up the water: but of this we have no settled observation.

Wherever vapours are generated in great abundance, and this at certain times; stated winds are there found to rise, at those times.

When stated winds blow in any place, and their cause be not found near at hand; such stated winds must be deemed foreign, and to come from far.

It is observed, that stated winds blow not in the night; but rise about three hours after the sun is up: whence they seem to be so weakened, or, as it were, tired with a long journey, that they can scarce break through the nocturnal condensation of the air; but are again quickened and recovered a little after sun-rising.

All stated winds are weak, except they blow from places near at hand; and ever yield to the winds that rise of a sudden.

There are many stated winds which we do not perceive, or observe, by reason of their weakness; as being suppressed, or over-powered, by the free winds: and are therefore scarce found

in the winter, when the free winds are most abroad; but rather towards the summer, when such wandering winds are stiller.

In Europe, the principal stated winds are, 1. northerly winds, from the solstice; and these both precede and follow the rise of the dog-star; 2. the west winds, from the autumnal equinox; and, 3. the east winds, from the vernal: but for the winter solstice, it is not much to be regarded, because of the changes and alterations whereto the winter is subject.

The bird-winds, (so called on account of their bringing birds from cold regions beyond the sea, into warmer) have no relation to stated winds; because they often deceive in point of time: but let them blow sooner or later, the birds wait for them; and frequently, after these winds begin to blow, they again fall off, and fail the birds, which thence drop into the sea, and sometimes upon ships.

There is hitherto discovered no way of predicting the return of the winds, to a certain day and hour; as there is in the case of the tides: some writers indeed, now and then fix a day for their return; but they do this rather from conjecture than certain observations.*

* Consult Bohun's discourse of Winds.

SECT. V.

OF SERVING WINDS; WITH REGARD TO THE FOURTH ARTICLE OF THE TABLE OF ENQUIRY.

TRANSITION.

THIS term of serving winds we have coined, to the end that observations upon them may not be lost; or confounded along with the others. Our meaning is this. Divide, for example, the year into three, four, or five parts, in whatever country; and if any wind blow there for two, three, or four of these parts; and a contrary wind but for one part; then the wind which blows oftenest we call the serving or waiting wind of that country. And the like may be understood of the weather.

The south and north winds are the serving winds of the world; for these and their divisions, blow more frequently over all the globe than the east and west winds, with their divisions.

All the free winds wait more upon the winter than the summer; but principally upon the autumn and the spring.

All the three winds wait more upon the regions without the tropics and polar circles, than

within them: for they generally blow little in the torrid and frigid zones; but frequently in the temperate.

So, likewise, all the free winds, especially the strongest of them, blow oftener, and more violently; in the morning and evening, than at noon and night.

The free winds are observed to blow more frequent in such countries as lie hollow and cavernous, than in such as are more firm and solid*.

ADMONITION.

Men have taken very little pains to observe these serving winds in particular countries; but if the thing were done, it would be useful in many respects. Upon asking a certain intelligent merchant, who was master of a colony in Newfoundland, and had wintered there himself, the reason why that country was reputed so extremely cold, beyond what the climate promised? he replied, the fact was not altogether so true as reported; but that the causes were two: the one, that the huge masses of ice brought down by the currents from the frozen sea, passed along the shores; the other, which he judged

* See hereafter, Sect. vii.

abundantly the more considerable, was, that the west wind there, blows for a much greater part of the year, than the east; as it does also, says he, in England; but at the fishery it blows cold from the continent; whereas, in England, it blows warm from the sea: but continues he, if the east wind blew so often, and so long in England as the west wind does at the fishery; the cold in England would be much more intense, and equal, perhaps, to what it is there*.

The west wind is the attendant of the afternoon; as generally blowing whilst the sun descends from the meridian: but this the east wind does much seldomer.

The south wind waits upon the night; as often rising and blowing strongly at that time: but the north wind tends more upon the day.

There are many and great differences between the serving winds of the sea, and those of the continent; especially in the particular which is said to have given Columbus the hint for discovering the West-Indies; viz. that the sea-winds are not stated, as the land-winds generally are. For as the sea abounds with vapours, which are in a manner present indifferently, and blow every way, with great inconstancy; as having

* See Mr. Boyle's History of Cold, passim.

no certain origins or fountains*: whilst the earth is very unequally provided of the matter of winds; some parts of its surface being well fitted for producing and increasing them; but others not; whence they here commonly blow from the place of their origin; and thence obtain their direction.

Acosta seems to differ from himself, when he says, in one place, that the south winds blow during almost the whole year in Peru, and along the coasts of the south-sea; but in another place, that the sea-winds principally blow along those shores: for the south wind there, is a land wind; so likewise are the north and the east; whilst only the west is a sea-wind in those parts. He seems exactest in the first case; viz. that the south is a waiting wind, and there familiar; unless perhaps from the name of the south-sea, he either conceived wrong, or expressed himself improperly, and by south meant the west-wind; because this blows from the south-sea. But the sea called the south-sea, is not properly a south-sea; but, as it were, a second western ocean, stretching in a like direction with the atlantic.

Sea-winds are doubtless moister than land-winds, yet purer; and such as easier and more

* See hereafter, sect. vii.

equably mix with a pure air: for land-winds are ill compounded and smoaky. Nor let it be objected, that sea-winds are grosser, because of the saltness of the sea; for the terrestrial nature of the salt does not suffer it to rise in vapour.

Sea-winds are warm or cold, according as they participate of the two qualities just now mentioned; viz. humidity and purity. By their humidity they mitigate the force of cold; (for dryness increases both cold and heat:) and again, they cool by their purity; whence without the tropics they are warm, but within them cold.

We judge that the sea winds are every where the serving winds of particular countries; especially on the coasts: as winds oftenest blow from the sea, by reason of the much greater stock of matter thence supplied to them than by the land; unless any stated wind should through some particular cause, chance to blow from the land. And let not stated winds be confounded with waiting winds; for waiting winds ever blow oftenest; but stated winds generally seldom; though this they both have in common with other winds, that they blow from the place where they are generated.

Sea winds are generally stronger than land winds; yet, when cease, the calm is greater out at sea than near the shore: insomuch that sailors sometimes chuse to keep within the winds of

the coast, rather than venture out; to avoid being becalmed.

Recurrent winds blow from the sea to the shore; that is, such winds as after having gone forwards for a while, turn back suddenly. And this seems owing to a certain refraction, and inequality, between the breezes of the sea, and those of the land; for all inequality of the air is the beginning of a wind. But these recurrent and variable winds chiefly happen in the bays of the sea.

There are breezes generally found about all great waters: especially in the morning: but more about rivers than at sea, by reason of the difference betwixt the breezes of the land, and those of the water.

Trees growing near the sea-shore are generally observed to bend away from the sea-breezes; as if they had some antipathy thereto: but this seems owing to the humidity and density of such breezes; which render them more ponderous and powerful.

SECT. VIII.

OF THE QUALITIES AND POWERS OF THE WINDS; IN PROSECUTION OF THE SIXTH AND FOURTEENTH ARTICLES OF THE TABLE OF ENQUIRY.

TRANSITION.

MEN have shewn little diligence, and curiosity, in observing the qualities, and powers of the winds. We shall here only select such particulars relating thereto, as are more stable and certain; leaving the lighter to the mercy of the winds.

The south wind with us, brings rain; and the north fair weather. The former gathering and fostering the clouds; the latter dissipating and dispersing them. Whence the poets, when they describe the deluge, feign the north wind at that time imprisoned; and the south-wind sent out with a very extensive commission.

The west wind is esteemed the wind of the golden age; the companion of perpetual spring; and the cherisher of flowers.

The school of Paracelsus, seeking a place for their three principles in the temple of Juno, that is, the air, have nitcht the south, the north, and the west; but excluded the east*.

* "Tincturis liquidum qui mercurialibus austrum,
Divitis et zephyri rorantes sulphure venas,
Et Boream tristi rigidum sale."

In England, we take the east for a pernicious wind: whence our common saying, "East is neither good for man nor beast."

The south wind blows after the sun has been present; but the north wind, after the sun has been absent in our hemisphere: the east wind, in the same direction with the air's motion; but the west wind always contrary thereto: the west wind, from the sea; the east, generally from the continent, in Europe and the western parts of Asia. And these are the more essential differences of the winds; upon which most of their powers and qualities depend.

The south wind is less anniversary, and stated, than the north; as also more variable and free: and when become stated, it is so gentle as to be scarce perceptible.

The south wind blows lower, and more laterally; but the north wind higher, and proceeds from above. This we mean not of the elevation and depression of the pole above mentioned; but that the south wind has its origin generally nearer the earth, and the north wind farther up from it.

Though the south wind brings rain with us, yet it brings fair weather in Africa, and causes great heats; Africa, however, is tolerably whole-

some: but if the south wind with us continue blowing fair weather without rain, for a considerable time, it proves very pestilential.

The south and west winds generate no vapours; but only blow from those quarters where the greatest quantity of vapours is collected by the increase of the sun's heat, which raises vapours; and therefore these are rainy winds: but if they proceed from dry places, that are free from vapours, they blow fair weather; though along with their purity they are sometimes sultry.

The south and west winds with us in England, seem confederates; being both of them warm and moist: on the other hand, the north and east winds seem related; as both of them are cold and dry.

The north and south winds blow oftener, as we touched above, than the east and west; because of the great inequality of vapours in the north and south parts, occasioned there by the absence and presence of the sun, which is, as it were, neutral or indifferent to the east and west.

The south wind from the sea is very wholesome; but more unhealthy from the continent: on the contrary, the north wind from the sea is to be suspected; but from the land it is wholesome. Again, the south wind blowing from the

sea is very beneficial to fruits and plants; driving away mildews, blasts and the like, from them.

A gentle south wind does not greatly collect clouds; but often proves serene; especially if it be of short continuance: but if it blow rough or long, it causes a cloudy sky, and brings on rain; though it does this rather when it ceases or begins to fall, than when it first rises, or continues in its strength.

The south wind, both in rising and falling, generally causes a change of weather; as from serene to cloudy; or from hot to cold: on the contrary, the north wind often rises and falls again, without altering the former state of the weather.

After frosts, or long continued snows, scarce any other wind blows besides the south; or if a concoction were now made of the frozen matters, which thus resolve: yet rain does not always follow hereupon; for there are some serene thaws.

The south wind rises oftener, and blows stronger, by night than by day; especially in winter nights: but the north wind, if contrary to its custom, it should rise by night, seldom continues above three days.

Greater waves roll to the shore when the south wind, than when the north wind blows;

though they were both to blow with equal force, or even the south wind weakest*.

When the south wind blows, the sea appears blue, or more bright; but when the north wind blows, it appears blacker and darker.

When the air grows warm of a sudden, it sometimes denotes rain; and, on the contrary, a cold gale sometimes does the same: but this follows according to the nature of the wind; for if the air grow warm with a south or east wind, it foretels rain at hand; and so likewise, when it grows cold with a north or west wind.

The south wind generally blows by itself, and unattended; but the north wind, especially that which is six points to the east, and the west two points to the north, are often attended with other different and contrary winds; whence they are resisted, and rendered tumultuary.

The north wind is to be avoided in the sowing of seed; and the south wind in the business of inoculating and engrafting.

The leaves of trees soonest fall off on the south side; but vines throw out their shoots to the south, and scarce have any other tendency.

Pliny observes, that in wide pasture grounds,

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* How is this certainly known?

shepherds should drive their flocks to the north side; that they may feed up to the south; because feeding against the north gives them lameness, blear-eyes and the scouring. He adds, that the north wind debilitates them for generation; so that if they were to copulate with this wind blowing in their faces, they would generally produce ewe-lambs: but in this, Pliny, acting only as a transcriber, is not very consistent.

There are three principal times when winds prove hurtful to growing corn; viz. 1. in the opening of the bud; 2. the going off the bloom; and, 3. near the time of ripening. In the latter case they empty the ear, or blow out the grain; and in the former two, either strike off the flower, or blast it in the stem.

With the south wind the breath of men smells stronger*, animals lose of their appetite, pestilential distempers are more frequent, colds common, and the bodies of men more indisposed and heavy: but with the north wind men are more brisk, healthy, and better in appetite. The

* A strong north, or north-easterly wind, has been found to have nearly the same effects on some tender bodies, as mercury; so as to occasion a fetid breath, loosen the teeth, cause a spitting, &c. And this has been more particularly observed some days or weeks after the taking of mercurial physic.

north wind, however, proves prejudicial to such as are troubled with the phthisick, coughs, the gout, or any sharp humour.

The east wind is drying, predatory, and destructive; but the west wind moist, moderate, and cherishing.

The east wind, blowing, when the spring is advanced, proves destructive to fruits; by bringing in caterpillars and other worms: so as scarce to spare the leaves; nor is it friendly to corn: the west wind, on the contrary, is very favourable and friendly to herbs, flowers, and all the vegetable tribe. The east wind, likewise, is somewhat favourable about the autumnal equinox.

The west winds are more boisterous, and ruffle and bend the trees more than those from the east.

A rainy season beginning with an east wind, continues longer than that which begins with a west wind; and generally lasts a whole day.

The east and north winds, after once they begin to blow, are more constant and fixed; but the south and west winds, more variable.

With a strong east wind all visible objects appear larger; but with a strong west wind, sounds are more audible, and reach to a greater distance.

The east-north-east wind, viz. six points to

the north, collects clouds; insomuch that this wind became proverbial among the Greeks, for a cloud-gatherer; whence they compared usurers to it, who, by letting out money fetch back more.* It is a violent but wide-spreading wind; so that it cannot drive away the clouds quick enough to prevent their resisting, and forcing back upon it; which is the cause also in large conflagrations, that make head and prevail against the winds.

The cardinal winds, as also the semi-cardinal, are not so strong as the median.

The median winds from north to north-east, are more serene; but from north-east to east more stormy. So likewise, from east to south-east, they are more serene; but from south-east to south, more stormy. So again, from south to south-west, more serene; and from south-west to west, more stormy. And so, lastly, from west to north-west more serene, but from north-west to west more stormy. So that, proceeding according to the order of the heavens, the median winds of the former semi-cardinal, are always more disposed to be calm; and those of the latter to be tempestuous†.

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* Cæsiam nubes ad se trahere.

† See the table of the divisions of the winds, sect. ii. whence this will appear more distinctly than it can well be expressed.

Thunder, lightning, and storms happen when cold winds blow; and such as participate of the north; viz. the west-north-west, north and by west, north-north-west, north-east and by north, and the east-north-east. And hence thunder is often accompanied with hail.

Snowy winds also come from the north; but these are such median winds as are not stormy: for example, the north-north-west; and the north-east and by east.

Winds obtain their nature and properties five several ways; viz. 1. from the absence or presence of the sun; 2. an agreement or disagreement with the natural motion of the air; 3. the difference of the matters whereof they are formed; as whether that of the sea, snow, lakes, &c. 4. the impregnation of the countries through which they pass; and 5. their local origins; whether on high; under the earth; or in the middle region; all which will be better explained in the following sections.

All the winds have a greater power of drying, even than the sun itself; because the sun raises vapours, but does not dissipate them, unless it beats very hot: whereas the wind both raises them, and carries them off. But of all the winds, the south has least of this effect; for stones and woodwork are observed to sweat more with a gentle south wind, than in a calm.

March winds are much more drying than summer winds; insomuch that the makers of musical instruments wait the return of March winds, for drying the matter of their instruments; and rendering it porous and sonorous.

All kinds of winds purge the air, and preserve it from corruption; insomuch that the most windy years are the most wholesome.

The sun has the fate of princes, whose governors of remote provinces, frequently have more submissive and obsequious subjects than the prince himself. Certainly the winds, which have their power and origin from the sun, govern and influence the temperatures of countries, and the disposition of the air, as much or more than the sun itself. Whence Peru is nearly as temperate, and its air as mild, as in Europe; because, by lying near the sea, and having very large rivers, and exceeding great and high mountains covered with snow, it receives a great supply of winds and breezes.

It is no wonder that the winds should have that force we observe of them, since violent winds are like inundations, torrents, and huge waves of the air; and yet, if carefully attended to, their power does not seem very extraordinary. Their violent effectsare, such as the blowing down of trees, which, being over-loaded with their own tops, afford a kind of sails for their own Subversion.

So likewise they may overturn houses, that are slightly built; but for solid buildings, they overturn them not; unless attended with earthquakes. Sometimes also, they sweep down whole magazines of snow from the mountains, and almost bury the vallies with it; an accident that befel Solyman in the Sultanian plains. Sometimes likewise they cause great inundations of water.

The winds sometimes blow whole rivers out of their channels, and leave their bottoms bare; for if a strong wind should, after a great drought, continue blowing several days, in the direction of the current, so as by tearing down the water, to drive it into the sea, and keep the sea-water from coming in, the river must necessarily become dry in many places.

ADMONITIONS.

When the poles are changed, the observations also, as to north and south, must change: for as the absence and presence of the sun is here the cause; this varies according as the north or south pole is elevated. But it may be an invariable thing, that there is more sea towards the south, and more land towards the north; which also contributes much to the difference of the winds.

Winds are generated a thousand ways, as we shall see presently; whence it is not easy to fix observations in a thing of so much uncertainty; but such as we lay down, will doubtless generally hold good.

SECT. VII.

THE HISTORY OF THE LOCAL ORIGINS OF WINDS; IN PROSECUTION OF THE SEVENTH ARTICLE OF THE TABLE OF ENQUIRY.

TRANSITION.

It is a difficult enquiry, to settle the local origin of the winds; since whence they come, and whither they go, is, even in scripture, remarked for a secret thing. And this we speak not as to the fountains of particular winds (of which hereafter;) but of the wombs of the winds in general. Some derive them from on high; some search for them in the deep; but there are few who seek them in the middle; where they are most frequently generated. And this is the manner of men, to pass over what lies before their feet, and look out for obscurities. Thus much is certain, that winds are either natives, or strangers, and as it were traders in vapours; importing

them collected into clouds, and exporting them again to and from different countries; whence winds are produced as by traffick and exchange. But our present enquiry is about native winds; for those which are foreign in some parts, are natives in others. There are then three local origins hereof; viz. 1. as they breathe out, or spring from the earth; 2. as they are thrown down from on high; and 3. as they are made up here in the body of the air. Those thrown down from above, are generated two ways; being either precipitated before they are formed into clouds; or afterwards, when the clouds are rarified and dispersed. We now proceed to their history.

The poets fable, that the kingdom of Æolus was seated in dens and caverns under the earth; where the winds were imprisoned, and sometimes let out.

Certain philosophical divines dwell upon these words of scripture: "Who brings forth the winds out of his treasures." As if the winds proceeded from certain subterraneal repositories, or magazines. But nothing can be built upon this; for the scripture likewise speaks of the "Treasures of snow and hail;" which, no one doubts, are generated above.

There is, doubtless, a large quantity of air contained in the bowels of the earth; and this,

probably may gradually breathe from thence; and sometimes upon particular causes rush out in a body.

An indirect phenomenon.

In great droughts and the midst of summer, when the earth cracks, large quantities of water are frequently observed to burst out in dry and sandy places: and if water, which is a gross body, sometimes does this; it is probable, that the subtile and rarified body of air may do it oftener.

When air breathes out of the earth gradually and in small parcels, it is little perceived, at first; but when many of these small eruptions come together, they make a wind; as a river is formed of springs. And this seems to be the case; because the ancients have observed, that many winds at their first rise, and in the places whence they rise, first blow weak; but afterwards grow stronger, in their progress; exactly after the manner of rivers.

There are some places found in the sea, and also some lakes, which swell very considerably, though no winds are there found to blow; whence this should seem owing to some subterraneous blasts.

A great quantity or force of subterraneous spirit or vapour, is necessary to shake or cleave the earth; but a less will serve to raise the water:

and therefore earthquakes seldom happen; but swellings and risings of the waters frequently.

It is likewise a common observation, that waters swell and rise a little before storms.

The weak subterraneous spirit or vapour, that escapes in small parcels, is not perceived upon the earth till it gathers into a wind; because of the porosity of the earth: but when it gets out from under the waters, it is presently perceived, from the swelling of the waters, by reason of their continuity.

We before observed*, that hollow and cavernous countries have their waiting or serving winds; insomuch that those winds may truly seem to have their local origins from the earth.

On large rocky mountains, the winds are found to blow both sooner, that is, before they are perceived in the vallies; and more frequent, that is, whilst the vallies enjoy a calm: but all mountains and rocks are cavernous.

In Denbighshire, in Wales, which is a mountainous and rocky country, there are said to be such strong eruptions of winds from certain caverns, as to toss back any kind of apparel thrown into them, a great height into the air.

There are certain holes, in a rocky cliff at Aber Barry, near the Severn, in Wales, whereto

* Sect. V.

if the ear be applied, various sounds and murmurs are heard under the earth.

An indirect phenomenon.

Acosta observes, that the towns of Plata and Potosi in Peru, lie not far asunder, and both of them situate in a rising or mountainous ground; so as not to differ in this respect; and yet that Potosi has a cold and wintery temperature of air; but Plata a mild and vernal one: which appears imputable to the silver mines near Potosi. And this seems to shew, that there are vents of heat and cold in the earth.

If the earth be the primum frigidum, as Parmenides would have it, on a supposition that cold is close linked in with density; it is no less probable that warm exhalations should arise from the central cold of the earth; than that the like should be thrown down by the cold of the upper region.

There are certain pits in Dalmatia, and the country of Cyrene, into which, as some of the ancients relate, if a stone be thrown, a storm will soon after be raised; as if the stone had broke some covering in the place where winds are imprisoned.

An indirect phenomenon.

Ætna, and many other mountains, cast up flames: in like manner, it is probable, that air

may break out; especially when expanded, and put into motion by subterraneal heat.

Certain noxious and foreign winds are observed to blow, both before and after earthquakes; in the same manner as a certain light and rarified smoke rises before and after great conflagrations.

ADMONITIONS.

1. Air, pent up in the earth is compelled to break out, for several reasons, as, 1. because sometimes the earth hangs loose together, and falls into a hollow; 2. sometimes the waters make a breach or ingulph themselves under the earth; 3. sometimes the air is expanded by subterraneal fires, so as to endeavour at more room; and 4. sometimes the earth, which before was solid, is burnt hollow, and reduced to ashes by fire; and thus being unable to support itself, falls in; with many other causes of the like kind. And so much for the first local origin of winds; viz. from subterraneal causes. We come next to their second origin, or that from above; viz. the middle region of the air, as it is called.

2. Let it not be supposed we any way deny that the other winds may likewise proceed from vapours of the earth and sea; but what we have spoke to, is the first kind, which come out of the earth, as winds already formed.

Woods are observed to murmur, before any winds are manifestly perceived; whence it is conjectured that the wind descends from on high. This is also observed in mountains; though the cause be here more doubtful, by reason of their caverns.

Winds follow upon the shooting of the stars, as it is vulgarly called, and come from that quarter where the star shot: whence it appears, that the air is in commotion above, before we feel the effects of it below.

The opening of the firmament and the scattering of the clouds, foreshew winds, before they blow upon the earth: which, again, is a proof that winds begin above.

The smaller stars are not perceived before the wind rises, though the night be clear: whence the air seems to be condensed, and rendered less transparent, by the matter which is afterwards resolved into wind.

Halos about the body of the moon; the sun setting blood-red; the moon rising red, on the fourth day after the change; with many other prognostics of winds derived from above, shew the matter of them to be there begun and prepared.

From these phenomena we may observe the difference already mentioned, as to the two ways wherein winds are generated above; viz. before

and after the collection of vapours into clouds: for the prognostics from halos, and the colour of the sun and moon depend, in some measure, upon cloudiness; but the shooting and appearance of the lesser stars, are observed in a clear sky.

When wind issues from a formed cloud, either the cloud is totally dissipated, and converted into wind; or separated, part into rain, and part into wind; or rent asunder, when the wind bursts out as in a storm.

There are every where many indirect phæno-mena in nature with regard to the reflection by cold; and therefore as the cold is very intense in the middle region of the air, vapours cannot, generally, break through that region; but must either be coagulated, or darted out again; according to the opinion of the ancients, which, in this particular, is just.

There is a third local origin of winds, here in the lower air; which we call by the name of swells or overcharges of the air: the thing itself is familiar and obvious; but hitherto passed over in silence.

EXPLANATION.

The generation of these winds in the lower air, proceeds after this plain manner. The air newly made of attenuated and rarified water and

vapour, being added to the former mass of the air, the whole can now no longer be contained in the same bounds; but increases, and rolls onwards, still possessing a greater space. Though this depends upon two suppositions; viz. 1. that a drop of water, converted into air, requires at least a hundred times more space than before; and 2. that a little new air in motion, being superadded to the old mass, disturbs and puts the whole in motion; like a small blast coming from a pair of bellows, or a crack in the window; which give a motion to all the air of a room, so as to disturb the flames of the candles.

As dews and mists are generated, here in the lower air, without being formed into clouds, or reaching to the middle region; the case is the same with many winds.

A continual breeze arises from the sea and waters; and this breeze is nothing more than a faint wind, newly generated.

The rainbow, which seems the lowest of all the meteors, and generated near the earth, is resolved into winds as much as into rain, if not more; when it appears not entire, but shortened at the ends, or broken.

Some winds have been observed, in countries separated by the interposition of mountains, to blow familiar on one side of those mountains;

without coming to the other: whence it is plain, that such winds are generated below the tops of those mountains.

There are numberless winds which blow in fair weather, and in countries where it never rains: these winds are generated where they blow, without having been clouds, or ever reaching so high as the middle region of the air.

An indirect phenomenon.

Whoever considers, how easily vapour is convertible into air; how great a quantity of vapour there is in the world; how much larger space a drop of water turned into air possesses than before; and how greatly air resists, upon but a moderate compression; can make no question that there must be winds every where generated, from the surface of the earth to the top of the atmosphere: for it is impossible that a large quantity of vapour, when it begins to expand, should be raised to the middle region of the air, without surcharging the air, and tumultuating in the way.

SECT. VIII.

OF THE ACCIDENTAL PRODUCTIONS OR GENERATIONS OF WINDS; WITH REGARD TO THE EIGHTH ARTICLE OF THE TABLE OF ENQUIRY.

TRANSITION.

We call those accidental productions of winds, which do not originally produce, or beget an impulsive motion of the wind; but either increase this motion by compression, return it by reflection, or cause it to agitate and roll by fluctuation: which proceeds from external causes, and the position of contiguous bodies.

In places where there are low hills, with vallies sinking about them, and again, higher mountains rising beyond these vallies, the air is more agitated, and the wind more perceived, than either on mountains or plains.

Winds and breezes are perceived in towns and cities, at the meeting of two streets; or where any wide place runs out into a narrow slip; and in the public passages near great buildings.

Cool rooms are made in houses, or happen accidentally by a stream of air passing through them, entering on one side, and going out at the other;

but this is done more effectually when the air enters in different directions, meeting in angles, and having a common exit in one corner. So likewise the arching of dining-rooms, or making them of a spherical figure, contributes much to their coolness; because, in this case, the air is moved and reflected in all directions. So again, winding porches are cooler than such as run strait; for a blast in a strait line, though not confined, but having a free exit, does not give such an unequal rolling, and undulatory motion to the air, as the meeting in angles, turning short, winding about, rolling round, and the like.

After great storms at sea, the accidental wind continues for a time, though the original wind be laid; as proceeding from a collision and percussion of the air, by the undulation of the waves.

The wind, in gardens, is commonly observed to be beat back by the walls, the building, and the banks; so as to make one imagine that it blows in a contrary direction to what it really does.

If hills inclose one side of a country, and the wind blow for some time against them from the plain, the wind, by the bare repercussion it sustains, is either condensed into rain, if it be a moist wind, or turned into a contrary wind for a small continuance.

Sailors frequently observe the wind to change, and vary, in the windings of promontories.

SECT. IX.

OF EXTRAORDINARY WINDS, AND SUDDEN GUSTS; WITH RELATION TO THE NINTH ARTICLE OF THE TABLE OF ENQUIRY.

TRANSITION.

SOME authors speak, and complain of extraordinary winds; such as hurricanes, tornados, fiery-winds, and several kinds of whirlwinds; but they give no description of the thing itself; which ought to be derived from annals, scattered history, and journals of the weather.

sudden gusts never happen in a clear sky; but are always attended with clouds and showers; so that there may justly seem to be, in this case, a certain eruption, a displosion of the blast, and a concussion of the waters.

Those storms called sea-monsters, which happen in misty, or foggy weather, supporting themselves like a pillar, are prodigiously violent, and dreaded at sea.*

* Storms at sea, are rare in foggy weather.

The greater tornados, which whirl round to any considerable distance, and snatch up things in their way, happen seldom; but the lesser, or sportful whirlwinds, are more frequent.

All hurricanes, tornados, and the greater whirlwinds, have a manifest, precipitate, or vibrating motion downwards, more than other winds; so that they seem to rush, like a torrent, and flow down, as in a channel; and afterwards to be beat back by the earth.

It happens frequently, that cocks of hay are carried out of the meadows into the air, and thence thrown down again, like a canopy. The same sometimes happens in fields of pease, or corn, whilst the crop is drying. So again, washed linen, hung out to dry, is sometimes carried up by a whirlwind, as high as the tops of trees or houses; and this happens without any great force, or violence of wind.

But sometimes these slight whirlwinds play in a very narrow compass, and even in fair weather; so that a person on horse-back, may [illegible] the dust, or light matters, taken up and whirled round, near him, without perceiving much wind at the same time. And this, doubtless, happens from contrary breezes mutually repelling each other; and causing a circulation of the air by the shock.

It is certain, that some winds leave behind

them, manifest signs of burning and scorching, on the plains and plants they pass over; but for the business of fiery winds, which are a kind of blind lightning, or boiling air, without flame; it properly belongs to the enquiry of thunder and lightning.*

SECT. X.

OF THE THINGS CONTRIBUTING TO ORIGINAL WINDS; IN PURSUANCE OF THE TENTH ARTICLE OF THE TABLE OF ENQUIRY.

TRANSITION.

WHAT the ancients have delivered upon the subject of winds, and their causes, is very confused, doubtful, and but seldom true. No wonder any one should not see clearly who stands remote. They speak as if the wind was something different from air in motion; as if exhalations generated, and made up the whole body of the winds; as if the matter of the winds were only a hot and dry exhalation; and lastly, as if the origin of the motion of the winds, was only a precipitation and percussion, from the cold of the middle region. All which are but arbitrary hy-

* See more to this purpose in Mr. Bohun of Winds.

potheses, and creatures of the imagination; and yet, from such threads as these, they have wove large webs, in imitation of the spider. But to consult nature upon the point; 1. every impulse of the air makes a wind; 2. the exhalations mixed with the air, contribute more to the motion than to the matter of winds; 3. moist vapours are, by a proportionate heat, easier resolved into wind than dry exhalations; and, 4. numerous winds are generated in the lower region of the air; and many breathe out of the earth; besides those which are drove back, and thrown down from above.

We observed, under the article of *General Winds*, that the natural rotation of the air, without any other external cause, produces a perceptible wind within the tropics, where the air revolves in larger circles.

Next to this natural motion of the air, before we proceed to enquire concerning the sun, which is the principal parent of the winds; we must see whether any thing may, from clear experience, be attributed to the moon and the stars.

Great and strong winds rise some hours before an eclipse of the moon; so that if the moon be eclipsed at midnight, the winds blow the same evening: but if the eclipse of the moon happen in the morning, they blow the midnight before.

Acosta observes, that in Peru, which is a very windy country, the winds blow most at the full-moon.

PRECEPT.

It well deserves to be observed, what effects the motions and changes of the moon have upon the winds; since they certainly have one upon the waters: as for example, whether the winds are not somewhat more boisterous in the new and full-moon, than in the quarters; the tides being affected in the like manner. For although it may seem a commodious hypothesis, that the moon rules over the waters; but the sun and stars over the air; yet it is certain, that water and air are very homogeneous bodies; and that, next to the sun, the moon has here the greatest power below.

It is observed, that the greatest winds blow about the time of the conjunctions of the planets.

Storms and tempests frequently happen at the rising of Orion: but it must be here examined, whether this happens not because that constellation rises at the time of year most disposed to produce winds; so as rather to be a concomitant than a cause. And the same question may justly be put, as to the rising of the Pleiades,

with regard to showers; and of Arcturus, with regard to storms*. And so much for the moon and stars.

Doubtless the sun is the primary efficient of many winds; as operating by his heat upon two kinds of matter; viz. the body of the air, and upon vapours and exhalations.

The sun, when powerful, expands even pure air; perhaps a third part of which is considerable: whence, by simple expansion, some breeze must necessarily arise in the path of the sun; especially in the times of greatest heat: and this rather two or three hours after the sun is up, than in the first of the morning†.

In Europe, the nights are sultry; but in Peru, the three first hours of the morning: and both for the same reason; viz. because the winds and breezes cease at those hours.

In a water-thermometer, the dilated air depresses the water, as if it were by a blast; but in a glass filled only with air, and capt with a bladder, the air, when dilated, blows up the bladder, like a manifest wind.

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* It will come to be considered, whether the rising of the constellations here mentioned, be meant of their cosmical or acronical risings; and whether the signs of this kind are not rather poetical than natural.

† See Dr. Jurin's Appendix to Varenius.

We made an experiment of this kind of wind, in a round turret, close shut up on all sides; by placing in the midst thereof a chafing-dish of coals, thoroughly ignited, to prevent their smoaking. On one side of the chafing-dish at some distance, we suspended a thread furnished with a cross of feathers, that it might be the more susceptible of motion; and now, when the heat was increased, and the air expanded, the feather-cross with its string, appeared to be agitated, and moved about various ways: then making a hole in the window of the turret, there issued out a warm exhalation; not in a continued stream, but by fits in an undulating manner.

So, likewise, the condensation of the air by cold after having been dilated, creates the same kind of wind, though weaker, by reason of the lesser force of the cold. And hence, in Peru, there is not only a greater coolness perceived under every little shade than here with us; but also a manifest breeze, from the shrinking and contracting of the air, when it enters the shade. And thus much for wind caused by a mere dilatation, and contraction of the air.

The winds proceeding from the mere motions of the air without any mixture of vapour, are soft and gentle. We must next examine into the vaporous winds, or those produced from vapour; which may prove as much stronger than

the former, as the expansion of a drop of water turned into air, exceeds the expansion of air, already produced; which it does by many degrees, as we before observed*.

Vaporous winds, which are those that commonly blow, are caused by the sun with its proportionate heat; and the matter of them are vapours and exhalations, converted and resolved into actual air; though not quite perfect at its first formation.

A small heat of the sun raises but little vapour; and therefore causes but little wind.

A moderate heat of the sun raises vapours, and does not presently disperse them again; so that, if the quantity thereof be large, they collect into rain, either alone, or attended with wind; but if the quantity be small, they are turned into simple wind.

The heat of the sun, upon its increase, has a greater tendency to the production of wind; but in its decrease, to the production of rain.

A strong and continued heat of the sun, rarifies, disperses, and sublimes the vapours; at the same time mixing them equably, and incorporating them with the air: whence the air becomes calm and serene.

Let the proper use be made of the Eoliple; and the proper experiments tried, in imitation of nature, for turning water, if possible, into true and permanent air.

A more equable and continued heat of the sun, is less disposed to produce winds; but an unequal, and changeable heat, is more disposed to produce them. Whence sailors, in a Russia voyage, are less exposed to winds than in the British channel, because of the long days; but in Peru, under the equinoxial, the winds come thick; by reason of the great inequalities of heat between the day and night.

Both the quantity and quality of vapours must be regarded. A small quantity produces gentle gales; and a middling quantity stronger winds; but a large one overloads the air, and produces rain either attended with a calm or wind.

Vapours arising from the sea, rivers, and lands overflowed, produce a much greater quantity of wind, than terrestrial exhalations; but the winds that arise from the earth, and drier places, are more obstinate and durable; and prove, generally such as are thrown from above: so that the opinion of the ancients has its use in this respect; only they thought fit to divide the right, and assign rains to the vapours, and nothing but exhalations to the winds; with the like distributions; which look pretty in discourse, though they are but empty at the bottom.

Winds proceeding from the melting of snow upon the tops of mountains are of a middle nature, betwixt aquatic and terrestrial winds;

but they rather incline to the aquatic: being, however, more sharp and active.

We formerly observed, that the melting of snow upon the snowy mountains, always produces stated winds on the side where it melts.

So likewise the anniversary north-winds, that happen about the rising of the dog-star, are thought to proceed from the frozen sea, and the parts about the artic-circle; where thaws happen late, or when the summer is advanced.

The huge masses, or mountains of ice, carried down towards Canada and Newfoundland, rather produce certain cold breezes, than variable winds.

The winds that blow from chalky and sandy lands, are few and dry; but in the hotter countries, sultry, suffocating, and scorching.

The winds arising from sea-vapours, easily fall back again into the rain, or the water whereof they are made; or, if they do not this, they soon mix along with the air, and grow quiet: but terrestrial, smoky, and uncteous exhalations, are resolved with greater difficulty, mount higher, are more irritated in their motion, frequently enter the middle region of the air, and help to compose the matter of fiery meteors.

It is reported here in England, that at the time when Gascony was under our jurisdiction, the subjects of Bourdeaux, and the neighbouring

parts, petitioned the king, that the burning of heath might be prohibited in Sussex and Hampshire; because it produced a wind about the end of April, destructive to their vines.

The meeting of strong winds one against another, produces violent whirlwinds; but if they are only gentle and moist, their meeting produces rain and a calm.

Winds are checked and allayed five ways; viz. 1. when the air loaded and tumultuating with vapours, is freed from them by their contracting themselves into rain; 2. when the vapours are rarified, dissipated, and so mixed kindly in along with the air, and grow quiet therewith; 3. when the vapours or exhalations, are raised up, or sublimed to a great height; so as to acquire a state of rest, till they either penetrate the middle region of the air, or are thrown down by it; 4. when vapours, collected into clouds, are carried into other countries by winds blowing from on high, so as not to disturb the countries over which they pass; and, 5. when the winds blowing from their origins, continue their motion a long way, without any new supply of matter; but at length slacken, lose of their force, and sink of course.

Showers generally allay the winds; especially such winds as are stormy: and winds, on the other hand, frequently keep up showers.

Winds contract themselves into rain, 1. either by being oppressed with weight, when the vapours are copious; or 2. by means of the contrary motions of gentle winds; 3. by the obstruction of mountains and promontories, which stop the force of the winds, and gradually turn them back upon themselves; and, 4. by intense cold, which condenses them. And this contraction into rain is the first and principal of the five ways whereby winds are laid.*

The smaller and more gentle winds generally rise in the morning, and fall when the sun sets; the nocturnal condensation of the air being sufficient to contract them: for air will suffer some degree of compressure without any great reluctance.

The ringing of bells is thought to dissipate thunder and lightning; but the same is not observed as to winds†.

Pliny relates, that the violence of a whirlwind may be broke by the playing of vinegar in amongst it.

ADMONITION.

Let the prognostics of winds be here consulted: for there is some connexion between causes and signs.

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* See above.

† It is reported that stormy winds are frequently laid by the firing of cannon, in sea-fights.

SECT. XI.

OF THE LIMITATIONS OF THE WINDS; IN PURSUANCE OF THE ELEVENTH ARTICLE OF THE TABLE OF ENQUIRY.

It is related of Mount Athos, and Mount Olympus, that the priests who yearly sacrificed upon their tops, used to find the writing they had drawn in the ashes of the sacrifice one year, no way disordered or obliterated, when they returned the next; although these altars did not stand in a temple, but in the open air, whence it is manifest, that at such a height there fell no showers, and blew no winds*.

They relate, that on the Peak of Teneriffe; as also upon the Andes, betwixt Peru and Chili; there lies snow along the cliffs and sides of the mountains; whilst upon the tops thereof the air is quiet; but so subtile as hardly to suffice for respiration; and so acrimonious and pungent as to inflame the eyes and give a nausea to the stomach.

Vaporous winds seem not to blow at any great height; though it is still probable that some of

† See hereafter, Sect. xiv.

them ascend higher than most clouds†. And so much for the height; next for the breadth of winds.

It is certain, that the spaces possessed by winds are very various; being sometimes extremely wide, and sometimes small and narrow. They have been found to range a hundred miles in a few miles.

Diffusive winds, if free, are generally vehement, and durable; commonly continuing twenty-four hours; but not rainy. On the contrary, narrow, or confined winds, are either gentle or stormy; but always short-lived.

Stated winds are itinerant: and travel over vast spaces.

Stormy winds run not out far; though always beyond the limits of the storm itself.

Sea-winds blow within much narrower bounds than land-winds; insomuch, that at sea they sometimes observe a brisk gale driving the waters on one side; as appears by the ruffling and curling thereof; whilst every where else there is a calm; and the sea remains as flat as a looking-glass.

We before observed, that little sportful whirlwinds sometimes play with the dust upon the road, like the blast of a pair of bellows. And so

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* Which is seldom high; or much above half, or a quarter of a mile, as has been often measured.

much for the extent of the winds: next or their duration.

Very strong winds at sea continue for a long while; as there receiving a large supply of vapour: but at land, they scarce continue above a day and a half.

Very gentle winds continue not to blow constantly, for above three days, either at sea or land.

The east wind, we before observed, is more lasting than the west; and whatever wind begins to blow in the morning, usually continues longer than that which rises in the evening.

It is certain, that winds rise and increase by degrees, unless when they are perfectly stormy; but fall quicker, and sometimes all at once.

SECT. XII.

OF THE SUCCESSIONS OF THE WINDS; WITH REGARD TO THE TWELFTH ARTICLE OF THE TABLE OF ENQUIRY.

When the wind changes conformably to the motion of the sun; that is, from east to south; from south to west; from west to north; and from north to east; it seldom goes back; or if it does, it is only for a short time: but if it moves in a contrary direction; viz. from east to north; from north to west; from west to south; and

from south to east; it generally returns to the former point, at least before it has gone through the whole circle.

If rain comes first, and the wind begins to blow upon it, the wind continues longer than the rain; but if the wind blow first, and is afterwards laid by the rain, the wind seldom returns; or if it does, it also rains afresh.

When winds continue to vary for a few hours, as if it were to try in which point they should settle, and afterwards begin to blow constant; they continue for many days.

If the south wind begins to blow for two or three days, the north wind will sometimes blow suddenly after it: but if the north wind blows for the same number of days; the south wind will not rise till after the east has blown a while.

When the year is upon the decline, and winter coming on; if the south wind blow at the beginning of the winter, and afterwards the north; the winter will prove frosty: but if the north wind blow at the beginning of the winter, and afterwards the south; the winter will be mild and warm.

Pliny relates from Eudoxus, that winds return in the same series every four years: which seems no way true; for the revolutions of the winds are not so quick. But the diligence of some has

reached so far as to observe, that the greater and more remarkable changes, such as heats, snows, frosts, warm winters, and cold summers, generally return in a circle of thirty years.

SECT. XIII.

OF THE MOTIONS OF THE WINDS; IN PURSUANCE OF THE THIRTEENTH ARTICLE OF THE TABLE OF ENQUIRY.

I.

TRANSITION.

MEN express themselves as if the wind were a certain body, that, of itself, impelled, and drove the air before it, by its own force; and when it changes, they speak as if the wind had removed itself to another place: and, whilst the populace talk in this manner, philosophers do not correct such notions; but, instead of stopping the error, give somewhat into the same themselves.

Having, therefore, already enquired into the local origins of winds; we are next to enquire into the excitation and direction of their motion. And for the winds which have their motion begun in their first impulse; as those have which are thrown down from above, or breathe out of the earth; the excitation of their motion is manifest: but others descend, and some ascend in their beginning; and afterwards acquire a rolling

motion, from the resistance of the air; chiefly according to the angles wherein their force is directed. But for such as are produced every where in the lower part of the atmosphere, as the commonest winds are, the enquiry about them seems difficult and obscure, though the thing itself be but vulgar; as we observed in the explanation under the seventh section.

We find some resemblance of this matter, in the close turret mentioned above: for we varied our experiment three ways: the first was that already mentioned, with a chafing-dish of charcoal thoroughly ignited. The second was, by using a vessel of hot water, without the chafing-dish; and then the motion of the feather-cross was slower, and less active than before; the dewy vapour of the water now hanging in the air, unresolved into the matter of wind, through the weakness of the heat. The third variation was made by continuing both the chafing-dish and the vessel of water in the room, and then the cross was agitated much more than ever; so as sometimes to be tossed upwards in an eddy, as if by a little whirlwind; the water now affording a quantity of vapour, and the fire adjacent driving and dispersing it about.*

* Experiments of this kind might easily be contrived and made; so as to give great light and information in many parts of the present subjects.

And therefore a principal cause of the excitation of the wind's motion, is the surcharging of the air, by a new addition of air produced from vapours. We proceed next, to the direction of the wind's motion; or its verticity, which is its change of direction.

The direction of the wind's progressive motion is governed by the nurseries, which serve as fountains to rivers; viz. such places as contain a larger collection of vapours; and are as the native country of winds. But when they find a current, or meet with little resistance from the air, then, like water in a declivity, they receive and sweep away all the light matter they find in their course, and mix it with their own stream, after the manner of rivers: and therefore winds always blow from the quarter where their springs or nurseries lie.

When the winds have no remarkable nurseries in a certain place, they change, or wander about extremely; and easily alter their current; as in the middle of the sea, and wide extended plains.

When there are great nurseries of winds in one place, but the winds receive small additions from the places they pass through, they blow strong at the beginning; and flag by degrees: on the contrary, where their nurseries are farther continued; they blow gently at first, and stronger afterwards.

There are moveable nurseries of winds; viz. in the clouds; which are frequently carried by the winds that blow aloft, into countries very distant from the origin of those vapours that produced the clouds: and in this case the nursery of the wind begins on that side, where the clouds begin to resolve into wind.

But the verticity of the winds does not happen, because the wind transports itself in blowing; but because it is either laid of itself, or subdued by another wind: and this whole affair depends upon the various situations of the nurseries of winds, and the varieties of times and seasons wherein the vapours issuing from these nurseries are resolved.

If there are nurseries of winds in opposite points; as one to the south, another to the north; the stronger wind will prevail, and blow constant, without any contrary wind appearing; yet so as to be somewhat checked and deadened by the weaker wind: as the tide is by the course of a river, where the motion of the sea prevails; though it be somewhat resisted by that of the river. But if one of the two contrary winds, which at first was the stronger, happens to fall; the other will now suddenly blow in its own contrary direction, wherein it blew before; though it lay concealed under the power of the stronger.

So, for example, if there be a nursery of wind to the north-east; the north-east wind will then blow: but if there be two nurseries, the one to the east, and the other to the north; the two respective winds will blow separate, for a certain tract; but, after their angle of confluence, they will blow north-east; or vary from that direction, according as one nursery proves stronger than the other.*

If there be a strong nursery of wind to the north, at twenty miles distance from any country, and a weaker to the east at ten miles distance; the east wind will blow first, for some hours; and soon after, when that has run its course, the north.

If the north wind blow, and meet a mountain in its way, from the west; it will soon after blow north-east; or a blast compounded of the original and the reflected wind.

If there be a nursery of winds in the earth, to the north, and the blast go right upwards, and meet a cold cloud from the west, which reflects it to the opposite point; it will blow north-east.

ADMONITION.

In the earth and sea the nurseries of winds are

* According to the common laws of motion and hydrostatics.

stable; so that their spring and origin may here be the better perceived: but being moveable in the clouds, the matter of them may be supplied in one place, and the winds formed in another; which occasions the direction of their motion to be more confused and uncertain. The cases above produced are in the way of examples, that may serve for all cases of the like kind. And so much for the direction of the wind's motion: but for the courses or voyages of the winds; though we have touched upon them before, under the title of the breadth of the winds, we must here enquire a little farther into them; since the breadth of the winds may be unskilfully taken for their length, if they should prove wider than they are long, in their sweep or progression.

If it were true, that Columbus could form a judgment of the continent of America from the stated western winds on the coast of Portugal; it would be certain that the winds might take a very long journey.

If it be true, that the thawing of the snows about Scandia and the frozen-sea, raises a north-wind in Italy, Greece, &c. in the dog-days, it is a very long way for winds to travel.

It has not hitherto been observed how much sooner, in order of the wind's motion, a storm comes to any place from one quarter, than from another: for example, how much sooner from

the east; with the wind at east; than from the west. And so much for the progressive motion of the winds: we come next to their undulation.

The winds undulate quick; so that even a strong wind fluctuates, or rises and falls alternately, at least a hundred times in an hour; which shews the force of the winds to be interrupted: whereas rivers, though rapid; and currents of the sea, though strong; have no undulation, except from the winds. Nor is this undulation of the winds any way equable; but, like the pulse, sometimes intermits, and sometimes returns double.

The undulation of the air differs from that of water in this, that in water, after the waves are risen they fall again spontaneously, to a flat: so that, notwithstanding the lofty poetical descriptions of tempests raising the waves to the skies, and sinking them again to the abyss; there is no considerable descent perceived of them, below the level surface of the water: but in the undulation of the air, where the motion of gravity is less, the air is raised and depressed almost equally. And so much for the undulation of the winds: next for their motion of conflict.

We have already made some enquiry into the conflicts and compound currents of the winds. It is manifest that winds, especially the gentle ones, blow indifferently any where; there being

few days or hours wherein some gentle breezes are not perceived in open places; and that with great inconstancy and variety: for those winds which proceed not from any larger nursery, wander and roll about, as if sporting with each other; sometimes meeting, and sometimes disjoining, and flying asunder.

Two contrary winds are sometimes observed to meet at sea; as appears from the ruffling of the surface of the water on either side of the ship; and the stillness of the water in the middle: and after the shock there one while ensues a general calm on the water; that is, when the winds equally break each other on both sides; and another while, a continued struggle and agitation of the water; when the stronger wind prevails.

The winds are certainly often observed to blow one way on the mountains of Peru; and, at the same time, a contrary way in the vallies below.

It is likewise certain, that the clouds, here with us, are driven one way, whilst the wind blows another.

Again, it is certain, that the higher clouds are sometimes found to fly over the lower; so as to go different, and even contrary ways; like opposite currents.

It is likewise certain, that there is sometimes a calm aloft in the air; whilst a rude storm blows below, for the space of half a mile.

On the other hand, there is sometimes a calm below, whilst the clouds move brisk above; tho' this happens but seldom.

Nor should the testimony of Virgil be wholly omitted; as he had some notion of natural philosophy. He makes the east, south-west, and west wind blow at once; and again all the winds to combat together.*

AN INDIRECT PHÆNOMENON.

It happens also in waves, that sometimes the upper, and sometimes the lower water moves the quickest; and sometimes, though rarely, there are found two different currents of water, one above and another below, moving in contrary directions. And thus much for the natural motions of the winds: we next proceed to their motions in artificial machines; but principally in the sails of ships.

II.

Of the motion of the winds, in the sails of ships.

We here chuse, for our example, the largest British ships, which have four and sometimes five masts, all standing erect, in a strait line, one behind another, along the middle of the ship. Their

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* Unâ Eurus, Notusque ruunt, creberque procellis
Africus.————
Omnia Ventorum concurrere prælia vidi.

names are the main-mast, which stands in the centre; the fore-mast, the mizzen-mast, which is sometimes double; and the bow-sprit.

Each mast consists of pieces, which may be crampt and joined to each other; and again taken down at pleasure: some have three, others but two of these pieces.

The bow-sprit stands inclined to the sea from its lower juncture; but from its upper, erect: and all the other masts stand perpendicular.

These masts are rigged with ten sails; and when the mizzen-mast is double, with twelve. The main-mast and fore-mast, have three tier of sails; which we call the main-sail, the top-sail, and the main-top-sail. The other masts have only two sails, without a main-top-sail.

The sails are spread a-cross, near the top of each joint of the mast, by means of certain rods, or yards, to which the upper part of the sail is fixed; the bottom is tied with ropes only at the corners; the main-sails being thus fastened to the sides of the ship; and the main-top-sails to the yards, immediately below them. And by the same ropes they are shifted, or turned, to either side, at pleasure.

The yard of every mast goes athwart the mast; only those of the mizzen-mast hang aslope; the one end being elevated, and the other depressed:

but in the rest they make right angles with the mast.

The sails of the main-mast, fore-mast, and bow-sprit, are of a quadrangular, or parallelogram figure; but the top and main-top-sails rise somewhat narrow; whilst the main-sail of the mizzen-mast is triangular; and the top-sail sharp or pointed.

A ship of eleven hundred tun, a hundred and twelve feet long in the keel, and forty feet wide in the hold, carried the main-sail of its main-mast forty-two feet deep, and eighty-seven feet wide.

The top-sail of the same mast was fifty feet deep; eighty-four feet wide at the basis; and forty-two at the top.

The main-top-sail was twenty-seven feet deep, forty-two feet wide at the basis, and twenty-one at the top.

The main-sail of the fore-mast was forty feet and an half deep, and seventy-two feet wide.

The top-sail of the same mast was forty-six feet and a half deep, sixty-nine feet wide at the basis, and thirty-six a-top.

The main-top-sail of the same mast was twenty-four feet deep, thirty-six feet wide at the basis, and eighteen a-top.

The mizzen-main-sail was fifty-one feet deep, from the elevated yard-arm, and seventy-two

feet wide where it joins to the yard; the other part ending sharp.

The top-mizzen-sail was thirty feet deep, fifty-seven feet wide at the base, and thirty a-top.

If there be two mizzen-masts, the sails of the hindmost, are less, by about a fifth part, than those of the foremost.

The main-sail of the bow-sprit was twenty-eight feet and a half deep, and sixty feet wide.

The top-sail thereof was twenty-five feet and a half deep, sixty feet wide at the base, and thirty a-top.

The proportions of the masts and sails of ships vary, not only with the rate or size of the ship, but also according to the different uses for which they are built; as whether for fight, freight, swift-sailing, &c. But there is no manner of correspondence between the dimensions of the sails, and the ships burden, or number of tuns she carries; for a ship of about five hundred tuns carries the main-sail of its main-mast but a few square feet less than another of twice the burden. Whence it is, that small ships are much better sailers than the larger; not only because of their lightness, but also because of the largeness of their sails, with respect to the bulk of the ship: for it would be an unwieldy and impracticable thing, to preserve this proportion in the larger shipping.

As all the sails are stretched full out at their tops, and fastened only by their corners at the bottom; the wind must of necessity swell the sails; especially towards the bottom, where they are slackest.

This swell of the sails is much greater in the main-sails, than in the rest; not only because those sails are parallelograms, and the others narrower upwards, or pointed; but again, because the width of the yard far exceeds the width betwixt the ship's two sides, to which it is fastened: whence, of necessity, these sails yield, by their slackness, a large bosom to the wind; insomuch, that in the great ship we have chose for our example, this swell, in sailing before the wind, may bulge out nine or ten feet from the plain of the sail.

And for the same reason, all sails swelled with wind, form themselves into an arch, at the bottom; so that much of the wind must necessarily miss them: and this arch, in the great ship abovementioned, will, in its height, equal the stature of a man.

But in the triangular sail of the mizzen-mast, the swell must needs be less than in a quadrangular sail; as well by reason of the less capacious figure, as because in a quadrangular sail there are three sides slack, and but two in a triangular

one: whence the wind is received more stiffy in the triangular sail.

The nearer the wind's motion comes to the head of the ship, the more powerful it proves, and sets her forward the faster; because it is spent upon a part where the waves are easiest cut by the sharp make of the prow: but principally, because a motion at the head draws the ship along; whilst a motion in the stern only protrudes her.

The wind's motion in the higher tiers of sails, sets the ship forwards more than in the lower tiers; because all strong motions are most effectual, when far removed from the resistance; as we see in levers, and the sails of the wind-mill: but for fear of over-setting the ship, the higher sails are made tapering, to prevent their carrying too much wind; and are chiefly used at such times when little wind is stirring.

When sails are placed in a strait line, one behind another, the hind-most must necessarily take the wind from the foremost, when it blows fore-right: and therefore, though they were all spread at once, yet the wind would have little force upon any more than those of the main-mast; and a little upon the main-sail of the bow-sprit.

The most commodious and advantageous disposition of the sails before a wind, is to hoist the

two lower sails of the fore-mast;* where, as we said, the motion is the more effectual: and again, also the top-sail of the main-mast; as there will still be left space enough underneath, for the wind to fill the lower fore-sails, without robbing them too much.

By reason of the back-sails thus taking the wind from the fore-sails, a ship makes more way with a side wind, than with a direct wind; for in a side wind, all the sails may be crowded, without taking the wind from one another; as they all turn side to side.

Again, the sails are stiffer stretched against a side wind; which stretching somewhat compresses the wind, and directs it to the part where it should blow: whence it acquires some additional strength. But that wind is the most advantageous which blows in the quarter, between a fore wind and the side one.†

The main-sail of the bow-sprit can scarce ever prove useless; as being not liable to be robbed of its wind; which it receives from that blowing every way about the ship's sides, and under the other sails.

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* Viz. near the ship's head.

† Ships differ greatly in sailing; according to accidental circumstances in their make, trimming, &c. Thus some ships that sail excellently with their masts upright, will scarce sail at all with them reclined; and vice versâ.

In the motion of the winds in ships, there is observed both an impulse, and a direction: but that direction which belongs to the rudder, does not greatly concern the present enquiry; only as it has a connection with the motion of the winds in the sails.

TRANSITION.

As the motion of impulse is in vigour at the head: so is the motion of direction at the stem; and therefore the main-sail of the mizzen-mast, is of great moment to the impulse; and proves, as it were, an assistant to the helm.

As the mariners-compass is divided into thirty-two points, so that each semi-circle thereof contains sixteen; a ship may sail in progression, without traversing, (as is usual in contrary winds,) even though of those sixteen points, ten be opposite; and only six of them favourable: but this greatly depends upon the main-mizzen-sail; for as the points of the wind now prevail which are contrary to the ship's course, and cannot be governed by the helm alone; they would turn the other sails, and the ship itself, a contrary way; but that this sail holding tort, favours the helm, strengthens its motion, and turns and brings about the ship's head into the way of her course.

All wind in the sails, somewhat loads and sinks the ship; and this the more, as it blows

from aloft: and therefore, in great storms, they first lower their yards, and down with the topsails; and next, if there be occasion, down with all the rest; even cutting away the masts themselves, and throwing their guns, lading, &c. over board; to lighten the ship, and keep her floating, at the mercy of the waves.

With a brisk and favourable gale, even a ship of burden may sail a hundred and twenty Italian miles in four and twenty hours. There are certain packet-boats, wholly built for sailing, that will make much more way. But when the wind is directly in their teeth; as a last, though feeble shift to advance, they traverse, or cut away cross and cross, out of their course; shifting their sails as the wind requires; then bend up towards their course again: and thus by repeating their angular trips, they get right forwards; though perhaps but at the rate of fifteen miles in twenty-four hours.

LARGER OBSERVATIONS.

THIS motion of the winds, in the sails of ships, has three principal origins, and fountains of its impulse, from whence it is derived; and from whence also, rules may be formed for increasing and strengthening it.

The first fountain is, from the quantity of the wind received; for it is plain, that much wind, here contributes more than a little; and there-

fore a sufficient quantity of wind must be carefully procured. The means to procure it is, in the way of thrift aad good husbandry, to prevent being robbed of it; and therefore, as much as possible, let no wind be lost, misemployed, or taken from the ship.

The wind blows either above the ship's sides, or below them, towards the surface of the sea; and as, in the way of good husbandry, it is usual to be very careful of small matters, (for every body takes care of large ones); so a particular regard must be had to these lower winds; though they doubtless are of less efficacy than the higher.

As for the winds which play chiefly about the ship's sides, and under the sails; it is the true office of the main-sail of the bow-sprit to prevent their being lost: this mast standing low, and aslope, so that its main-sail may receive them; and therefore become serviceable, without taking from the winds intended to fill the other sails. And, with regard to this point, we do not see what human industry can do more; unless it were to spread the like kind of low sails, in the manner of wings, from the middle of the ship; two on both sides; when the wind blows fore-right.

In order to prevent the fore-sails from being robbed by the back-sails, in fore-right sailing; there seems to be no other method left, but to

range the sails in the form of a pair of steps, mounting upwards from stern to stem, so that the sails of the mizzen-mast may hang the lowest, those of the main-mast in the middle, and those of the fore-mast highest; whence one sail will not hinder, but rather assist, and serve another; by giving and transmitting the wind thereto. But this only holds good in sailing before the wind; for in a side wind, all the sails co-operate. And so much for the first fountain of impulse.

The second fountain of impulse arises from the manner wherein the wind strikes the sail; for if, through the contraction of the wind, the stroke be sharp and sudden, it will give the greater motion; but if diffused and languid the less.

And with regard thereto, it is of very great moment, that the sails should receive but a moderate swell and extension: for if they be too tort, they will rebound the wind like a wall; and if too slack, the impulse will prove weak.

And here human industry has succeeded in some particulars, though rather by chance than by judgment; for, in a side wind, they contract that part of the sail, as much as possible, which is opposite to the wind; and by this means throw the wind into the other part where they would have it blow. And this, indeed, they do

by design; though, perhaps, without considering, that besides this, the wind is at the same time necessarily contracted; and so has a sharper percussion.

What farther improvement may here be made, we do not well perceive; unless the figure of the sails were altered; and some of them made not to swell spherical, but spur-fashion; with the yard in the middle of the bend: so that the wind, being contracted towards a point, might not only have a smarter percussion; but the sail also the better cut the resisting air. And we know not what might be the effect of having a sail within a sail: that is, to fix a kind of purse in the middle of a large sail; and keep it astrut with splices of wood; so as to collect the wind in the middle of the large sail, and bring it to a kind of point.

The third fountain of impulse, proceeds from the place where the percussion is made; and is of two kinds: for the impulse is easier and stronger on the fore-part, than on the hind part of the ship; and on the upper-part of the masts and sails, than on the lower.

Nor do men seem to have been ignorant hereof; as laying the greatest stress upon the sails of the fore-mast in sailing before the wind; and spreading their main-top-sails in calms. And we can think of no farther improvement, at present,

in this respect; unless as to the first case, it be to have two or three fore-masts; the middle one erect, and the others inclined, with their sails hanging right-down; and in the second, to enlarge the fore-mast sails, at the top, or to make them less tapering than usual: but in both cases so as to prevent all danger from sinking the ship too much.

III.

Of the motion of the wind in other machines of human invention.

THE motion of a wind-mill has no difficulty in it; and yet it is, usually, neither well demonstrated nor explained. The sails are set directly facing the wind that blows; but one side of each sail lies more to the wind, whilst the other gradually slopes away from it. But the revolving motion always begins from the lower side; which is farther removed from the wind. And now the wind, blowing against the machine, is compressed by the four sails; and obliged to take its course through the open spaces between them: whence the wind in this compressed state, of necessity brushes smartly against the edges of the sails, and turns them round; as a top, or the like, is turned, or set up, by a flirt of the finger.

If the sails were stretched out equally, it is a question which way they would incline; as in

the falling of a stick: but as the first side that meets the wind, throws the force of the wind upon the lower side; and this again throws it into the vacuities; this lower side receives the chief impulse of the wind; whence the rotation presently begins on that part: for it is not the first impulse of the wind in front;* but a lateral impulse, after the compression, that begins the motion.

To this purpose we made several experiments upon paper-sails, turned with the blast of bellows. 1. And first, we added a fold to the lower side of the sail turning away from the blast, which now coming side-ways, might have a larger surface to strike against: but this had no good effect; the additional fold not assisting the percussion of the wind, so much as it hindered the sails from cutting the air. 2. Next we placed obstacles at some distance behind the sails, the whole breadth of them all; that the wind being more compressed, might strike the stronger: but this rather did harm: as the repercussion checked the primary motion. 3. Lastly, we made the sails double their former width, that the wind might be compressed the more; and have a stronger lateral percussion: and this succeed-

* Which directly tends to overset the mill.

ed extremely; so that the sails turned with a much gentler blast; and revolved with a far greater velocity.

PRECEPTS.

Perhaps this increase of motion may be more commodiously procured by six or eight sails, than by four of twice the breadth; unless the bulk should be too great for the motion. But of this let trial be made.*

The length of the sails also contributes to the motion: for in all rotations, a small force applied towards the circumference, is equal to a much greater towards the centre. But the lengthening of the sails has this inconvenience, that the longer they are, the wider they stand from one another at top; and the less the wind is compressed. It might perhaps succeed to have the sail somewhat long, and widening towards the top, like an oar: but this we have not tried.

ADMONITIONS.

If these experiments be reduced to practice in wind-mills, the whole machine must have strength in its structure; especially in its foundation: for the more the wind is compressed,

* Enquire the success of a full circle of sails, placed valve-fashion, for the wind to slip through; as in the wind-mill at Deptford-bridge, near London.

though it whirls the sails round the faster; yet it also gives the greater shock to the mill.

It is reported, that there are, in certain parts, wind coaches, or caravans, driven with sails; which is an affair that should be well enquired into.*

PRECEPT.

Carriages to move by the wind are impracticable, except in plains, and open places. And even here also, what must be done when the wind fails? It is more rational to think of easing the motion of waggons, and carriages, by moveable sails, to take up and down; which might favour the horses, and ease their labour; than pretend to drive by land with the wind alone.

SECT. XIV.

OF THE PRESAGES OR PROGNOSTICS OF THE WINDS; IN PROSECUTION OF THE FIFTEENTH ARTICLE OF THE TABLE OF ENQUIRY.

TRANSITION.

The more divination has been corrupted with vanity and superstition; the more the purer part

* Accounts and descriptions of this kind are to be met with in voyages to the eastern countries; but how far they may be safely relied upon is not certain. And such kind

10821

of it should be received and regarded. But natural divination is sometimes more, and sometimes less certain; according to the nature of the subject whereon it is exercised: so that in a subject of a constant and regular nature, it affords a true prediction; but in things of a various, compounded, and casual nature, one that is fallacious. And yet, even in a variable subject, predictions will generally hold true, if care be used in forming the rules; or not err greatly, though it should not hit upon the precise time of events. But even in point of time, some predictions will come very near; particularly such as are derived not from causes, but from the actual beginnings of things; though they manifest themselves sooner, in a prepared and well-disposed matter than otherwise. We now, therefore proceed to the prognostics of winds; wherewith we shall necessarily intermix some others, concerning rain and fair weather: which cannot well be separated from the former: but leave the particular enquiries about them to their own proper titles and history.

If the sun appear concave at its rising, the

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of contrivances seem chiefly used in sandy deserts; the sand here in some measure answering to water; so as to make the motion a kind of sailing.

day will prove windy; or showery: if the concavity seem shallow, windy; but if deep, showery.

The sun rising pale, or, as we vulgarly express it, watery, denotes rain; and if it set pale, wind.

If the body of the sun set blood-red, it foretels great winds, for many days.

If, at sun-rising, his rays appear fiery, not yellow; it denotes rain rather than wind. Understand the same of his setting.

If, at the rising or setting of the sun, his rays appear contracted, or shortened, and do not shine out bright; though the weather be not cloudy; it denotes rain rather than wind.

If, before sun-rising, there appear over-early rays; it denotes both wind and rain.

If, at sun-rising, the sun throws his rays from the clouds, whilst one half of his body remains clouded; it foreshews rain; especially if those rays strike downwards, so as to shew the sun bearded: but if the rays break from the middle, or from several parts, whilst the sun's external face remains covered with clouds; it signifies great storms both of wind and rain.

If the rising sun be encompassed with a circle, wind may be expected from that quarter where the circle shall open; but if the whole circle shall vanish equably, it is a sign of fair weather.

If, towards sun-set, he appears with a white circle about him, it promises a little storm the same night; but if the circle be black, or dusky, it portends a great wind the next day.

The clouds looking red at sun-rising, prognosticate wind; but at sun-setting, fair weather the day following.

When at sun-rising clouds gather themselves near the sun's body; it promises a severe storm the same day: but if they fly from the east to the west, it denotes fair weather.

If, at sun-rising, the clouds disperse from about the sun, some to the south and others to the north; though the sky seems clear near the sun itself; yet this prognosticates wind.

If the sun, at setting, be wrapt in a cloud; it denotes rain the next day: but if it actually rain at sun-set, it rather denotes wind; or, if the clouds seem to be drawn towards the sun, it denotes both wind and storms.

When the clouds, at sun-rising, seem not to encompass the sun, but to hang over him, as if to eclipse him; this portends winds to arise from that quarter where the clouds incline, but happening at noon, it denotes both wind and rain.

When clouds every way block up the sun, the less light there is left and the smaller the disk of the sun appears, the more raging will be the

storm: but if the sun's body should appear double, or treble, as if there were two or three suns, the more severe will the tempest prove, and continue for many days.

The new-moon shews the dispositions of the air, though, principally on the fourth day, when her newness seems confirmed: but the full moon is a stronger prognostic than any of the days that succeed it.

By long observation, the fifth day of the moon is held suspected, at sea, for stormy.

If the new moon does not appear till the fourth day, it prognosticates a troubled air for the whole month.

If the new-moon, either at her first appearance, or within a few days after, has her lower horn obscure, dusky, or any way sullied; it denotes foul weather and storms before the full: but if she be discoloured in the middle, storms are to be expected about the full; or about the wane, if her upper horn be affected in like manner.

When the moon, on her fourth day, appears pure and spotless, her horns unblunted, and neither lying flat nor standing erect, but betwixt both; it promises fair weather, for the greatest part, till new moon again.

If at this time she rises red, it portends wind;

if reddish, or dusky, rain: but it denotes neither beyond the full.

An erect moon is generally threatening, and unfavourable; but particularly denotes winds: though if she appear with short and blunted horns, it rather denotes rain.

If one horn of the moon shall be more pointed and crest, and the other more obtuse; it rather denotes wind: but if both, it denotes rain.

A circle, or halo, about the moon, rather denotes rain than wind; but if she appear erect, within the circle, it portends both.

Circles about the moon always denote winds, on that side where they break: and a remarkable brightness of the circle, in any part, denotes winds from that part.

Double or treble circles about the moon, portend severe and dreadful tempests; and much more if those circles are not entire, but broken and spotted.

The colours and halos attending the full-moon, afford nearly the same presages as the moon's fourth day; but the accomplishment is more immediate.

The full-moon is generally more attended with fair weather, than other ages of the moon; but sometimes, in the winter with intense cold.

The moon appearing larger about sun-set, yet luminous and not dusky, promises fair weather for many days.

An eclipse of the moon is commonly attended with wind; an eclipse of the sun, with fair weather; and seldom either of them with rain.

Wind is to be expected both before and after the conjunctions of all the planets with one another; but fair weather after their conjunctions with the sun.

Mild rains and showers follow upon the rising of the Pleiades, and Hyades; but storms upon the rising of Orion and Arcturus.

Shooting stars, as they are commonly called, foretel winds to arise from that quarter whence such supposed stars darted: but if they fly from several and contrary parts; it denotes great tempests both of wind and rain.

When the small stars are not visible, any where in the sky; it presages great storms and rains, within a few days: but if these small stars are obscured in some parts, and clear in others, it foretels only wind; but sooner.

An equably bright heaven at the new-moon, or on her fourth day, presages fair weather for several days; when uniformly obscure, showers; but when interruptedly obscure, winds from that quarter where the obscurity is. And if the heavens grow dark on a sudden, without cloud or fog to intercept the brightness of the stars; it is a sign that rough and severe storms are at hand.

When an entire circle surrounds a planet, or

any large fixed star, it presages rain; but if the circle be broke, winds, from that quarter where the breach is.

When it thunders more than lightens, expect great winds: but if it lightens frequently between the thunder-claps, expect hasty showers with large drops.

Thunder in the morning foreshews wind: and in the afternoon, showers.

Loud thunder, if it roll and pass by the place where it is heard, denotes winds; but that consisting of unequal and sharp claps, denotes storms, both of wind and rain.

If it lightens, and the sky be clear, winds and rain are soon to be expected, from the quarter where the lightning happens; but if it lightens from different parts of the sky, severe and dreadful tempests are to follow.

When it lightens from the cold quarters of the heavens, as the north and north-east; hail usually follows: but if from the warmer, as the south and west, sultry showers.

Great heats, after the summer's solstice, generally end in thunder and lightning; or if these succeed not, terminate in wind and rain, that last for many days.

The fiery ball which is seen at sea, and called Castor by the ancients, if it be single, prognosti- a severe tempest; and so much the more, not adhere to the mast of the ship, but

rolls or dances about: but if there appear two of them, or both Castor and Pollux, together, when the storm is grown stronger, this is reckoned a good sign; but if there be three of them, or Helena also attending, the tempest becomes more outrageous: so that the appearance of one alone, denotes crudity in the tempestuous matter; two a concoction or ripeness thereof; but three or more, such a large collection as is dissipated with difficulty.

If the clouds drive fast whilst the sky is clear, let winds be expected from that quarter whereto the clouds are driven; but if they collect and roll up together, they will afterwards begin to separate and disperse, when the sun approaches to that part where they are collected: and if they disperse more towards the north, it denotes wind; but if to the south, rain.

The clouds rising black or dusky at the setting of the sun, denotes rain the same night, if they rise opposite to the sun, or in the east; but the next day, attended with wind, if they rise near the sun, or from the west.

The sky clearing up, or the clouds breaking away into a part opposite to the wind that blows, denotes fair weather; but clearing up towards the wind, it yields no certain prognostic.

Sometimes there are several floors or stories of clouds, one above another; five whereof Dr.

Gilbert declares, he has sometimes observed at once; but the lowest are always blackest: though it may sometimes appear otherwise; because the whiter strike the sight most. A double range of them, if thick, denotes approaching rain; especially if the lower cloud seem swoln: and more floorings denote the continuance of rain from day to day.

When the clouds appear fleecy, and are dispersed up and down the sky, they denote storms; but if they appear to warp over one another, like scales, or the tiling of a house, they promise dry and fair weather.

Feathered clouds, or such as appear like the branches of the palm-tree, or the flower-de-luce; denotes showers at hand or not far off.

When hills and mountains appear, as it were, with their caps on, from the clouds that hang about and surround them; it is a sign of impending storms.

Clouds appearing of an amber or gold colour, before sun-set, and having, as it were, their edges gilt with gold; promise fair weather after the sun is gone down lower.

Clouds that appear muddy and dirty, prognosticate wind and rain at hand.

The sudden appearance of a light cloud, in a clear sky; especially coming from the west, or about the south; denotes a storm a-brewing.

The appearance of a white pregnant cloud, called by the ancients a white tempest; denotes small hail in the summer, and snow in the winter.

When mists and fogs rise upwards, they denote rain; if they mount suddenly, as if they were sucked up, they foreshew winds; but when they fall, and remain in the vallies, fair weather.

A serene autumn denotes a windy winter; a windy winter, a rainy spring; a rainy spring, a serene summer; a serene summer, a windy autumn: so that the air, upon a ballance, is seldom debtor to itself. Nor do the seasons succeed each other in the same tenor, for two years together.

When our common fires burn paler than usual, and murmur or resound within, it is a sign of a storm; if the flame curls, bends, and waves in its rising, it principally denotes wind; but spongy excrescences in the snuffs of candles and lamps, rather denote rain.

When coals burn bright and shining, it is a sign of wind; so, likewise, when they quickly deposit and throw off their ashes.

When the sea appears calm on its surface from the land, and yet has a murmuring noise, though without swelling, this foretels wind.

The sounding of the shores in a calm, and the

ringing of the sea itself, with a certain flutter, or kind of echo, heard more distinctly, and to a greater distance than usual, prognosticates winds.

The appearance of froth, white crowns, or bubbles of water up and down, on the surface of the sea, whilst it lies flat and calm, denotes winds; and when these signs are more remarkable, severe tempests.

The appearance of a shining froth, called sea-lungs, upon a rough and turbulent sea, denotes a continuance of the tempest for many days.

When the sea swells without a noise, and rises to the shore higher than usual; or if the tide comes in fresher than ordinary; this prognosticates winds.

A sound coming from high hills, and a murmuring noise rising in the woods, as also a kind of crackling in open places, foretels winds; so likewise an unusual murmuring in the heavens, without thunder, principally denotes winds.

Leaves and chaff playing in the air, without any sensible breeze; the down of plants flying about; and feathers floating and playing upon the waters: denote winds at hand.

Water-fowl flying and flocking together; but particularly mews, gulls, and moor-hens, quitting the sea or rivers, and hastening to the

shores or banks, especially if with a cry; and again, their playing on the dry land, foretels winds; especially if this happen in the morning.

On the contrary; when land-fowl go to the water, strike it with their wings, wash themselves, and raise their cry; but especially the crow; this portends tempests.

Ducks and coots or didappers, are observed to prune their feathers before wind; but geese with their importunate gaggle, seem to call down rain.

When the heron tours upright, so as sometimes to fly above a low cloud; this denotes wind; but the high flight of a kite denotes fair weather.

The continued croaking of the raven, in a sobbing manner, presages wind; but if it be by fits, in a stifled manner; or if the croak be repeated at longer intervals, it denotes rain.

The whooping of the owl was thought, by the ancients, to denote a change of weather, from fair to rain, or from cloudy to fair: but with us, if the owl whoops free and clear, it generally denotes fair weather; especially in winter.

If the birds which roost on trees fly early to their nest, and quit their feeding soon, it presages storms; but when the heron stands melancholy upon the sand, or the raven stalks about, it denotes only rain.

When dolphins play in a calm at sea, this is

thought to foretel wind from that quarter whence the dolphins come; on the contrary, their playing, and throwing the water about, in a rough sea, denotes fair weather: but for most other kinds of fish; their swimming a-top, and sometimes leaping out of the water, denotes rain.

Hogs are so disturbed, affrighted, and strangely affected at the rising of wind, that the country people have a notion, this is the only creature that can see the wind; and imagine it a frightful sight.

Spiders ply their work hard before wind; as if they snatched the opportunity of spinning their webs, before the wind should come to prevent them.

The ringing of bells is heard to a greater distance before rain; but before wind more unequally: the sound coming and going, as it does when the wind blows strong.

Pliny delivers it as certain, that trefoil bristles and pricks up its leaves against a storm.

He likewise adds, that vessels containing eatables, will sometimes leave a sweat behind them in the buttery where they stood; and that this prognosticates severe tempests.

ADMONITION.

Since rain and winds have nearly the same common matter; and since some condensation of the air always precedes wind; because the

new-made air is received within the old; as appears by the ringing of the shores, &c. the high flight of the heron, &c. and since, in like manner, a condensation of the air always precedes rain; it follows, that rain must have many prognostics in common with wind; for which, the prognostics of rain, should be consulted under the particular history of that meteor.*

SECT. XV.

OF IMITATING THE WINDS; IN REGARD TO THE SIXTEENTH ARTICLE OF THE TABLE OF ENQUIRY.

TRANSITION.

If men could but persuade themselves, not to pin their minds down to the sole consideration of the subject they propose; so as to forget every thing else, as little to the purpose; which they subtilize and speculate for ever upon it, as they generally do, in a fruitless manner; they could not be so stupefied as they commonly appear; but would transfer their thought, and, by reasoning, discover many things at a distance, which

* But this history is not hitherto extant, that we know of. If proper histories of all the meteors were wrote, though it were in no greater perfection than the present history of winds, they might afford much light to one another.

lay hid nearer hand. It were, therefore, proper to transfer the method and conduct observed in the law, to the law of nature; and proceed in natural enquiries with the same sagacity and reasoning, from parallels and similitudes, as we practice in law-cases.*

Bellows, with men, are the store-vessels of wind; from whence we derive it, in proportion to our wants and abilities. The vallies and interstices of mountains, and the open windings and turnings betwixt buildings, are but larger kinds of bellows. The principal uses of bellows, are the animating of fire; and blowing the organ. They act by drawing in the air, to prevent a vacuum, as the phrase is; and driving it out again by compression.

We likewise use hand-fans for coolness, and the making a wind. These impel the air but gently.*

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* Let the present history serve for an example; wherein all nature and art seems to have been searched, with a view to the subject; and matters brought in for it from every quarter. When all the materials belonging to the subject are thus found, collected, and ranged in their properest order, so as to afford a perfect set of tables, with their axioms; and fully exhibit the thing as it is in nature; then will the enquiry be finished, and not before. See the Novum Organum, Part ii.

† Add here the common method of winnowing by the gewe-fan; shooting with the wind-gun, &c.

We have already mentioned a method of making rooms cool in summer;* but more curious and exact ways may be discovered, especially if, in the manner of bellows, the air was drawn in at one part, and discharged at another. But the methods at present in use for this purpose, turn only upon compression.

There is a great agreement between the winds of the world, and the flatulencies in the body of man, and other animals: for these also are generated from moisture, and alter with it; as winds and rains do. They are also dissipated, and made to perspire, by a stronger heat. And hence an observation may be transferred to the winds; viz. their being produced from a matter affording a tenacious vapour, that is not easily dissipated; as we find by beans, pulse and fruit; which proves the case also in the greater winds.

In the distillation of vitriol, and other fossils, which are flatulent and explosive, they are obliged to use large receivers, to prevent their being broke.†

The wind made by the nitre in gunpowder, bursting out of a sudden, and blowing the flame

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* See Sect. VII. Accidental Generations of Winds.

† Here enumerate the bodies that generate most air by distillation; viz. tartar, tallow, &c. See Mr. Hales's Vegetable Statics

along, not only equals, but exceeds all other winds; excepting those of thunder.

The force of the wind is compressed in machines, and engines of human invention; as in guns, mines, and powder-houses, when they fire and blow up; but it has not hitherto been experienced, whether if a large quantity of gun-powder were fired in the open air, it would raise a wind, by the commotion of the air, that should last several hours.*

There is a flatulent and expansive spirit concealed in quicksilver; so as to make it, in effect, resemble gunpowder: and a little of it mixed along with gunpowder, makes the powder stronger. The chemists also speak of gold, as if in some ways of preparing, it would make an explosion, almost like thunder.†

A LARGER OBSERVATION.

The motion of the winds is, in many respects, seen, as in a glass, by the motion of the waters. 1. Great winds are inundations of the air, like inundations of the water; both proceeding from an increase of quantity. 2. As waters either descend from above, or flow from the earth; so some winds are thrown down from on high, and some rise up from below. 3. As sometimes in rivers

* As the firing of great guns is said to allay storms.

† This seems meant of the aurum fulminans.

there are contrary motions, one motion of the tide, another of the river's course; and yet but a single motion takes place; that of the tide becoming predominant: so, likewise, when contrary winds blow, the greater subdues the less. 4. As it sometimes happens in currents of the sea, and certain rivers, that the water a-top moves in a contrary direction to that below; so, likewise, in the air, when contrary winds blow, together, the one flies over the other. 5. As there are cataracts of rain falling within a narrow compass; so there are, in like manner, narrow eddies of wind, or whirlwinds. 6. As waters, when disturbed, will have an undulation, besides their progressive motion; so likewise have the winds. And besides these, there are other correspondences between them, derivable from the present enquiry.

SECT. XVI.

IMPERFECT AXIOMS; OR VARIABLE CANONS, FORMED UPON THE PRECEDING ENQUIRY.

TRANSITION.

CANONS, or axioms, are either particular or general; but both of them with us are variable or improveable: for we dare not yet pronounce upon any thing. As to particular axioms, they

may be deduced and collected from almost every article; but we shall here subjoin a few of the general ones, that we have ourselves drawn out.*

Axiom I. Wind is nothing more than air put into motion, either by a simple impulse, or the admixture of vapours.

II. Winds are produced by the simple impulse of the air, four ways; viz. 1. by the natural motion of the air; 2. by the expansion of the air in the path of the sun; 3. the contraction of the air by sudden cold; and, 4. by the compression of the air from external bodies.

There may possibly be a fifth way; viz. by the agitation and concussion of the air from the stars: but operations of this kind should not be mentioned yet;† or else should be but sparingly received.

III. The principal cause of winds, produced by the admixture of vapours, is, the air's being over-loaded by the air newly formed from vapours; whence the bulk of the air increases, and requires more room.

IV. A small, fresh supply of air may cause a great swell, every way, in the atmosphere; so that

* See Novum Organum, Part ii. Aph. V.

† 'Till better known and discovered; or till natural philosophy itself is farther advanced.

this new air, from the resolution of vapours, contributes more to the motion than the matter: but the great body of the wind consists of the former air. And the new air does not drive the old air before it, as if they were separate bodies; but both being mixed together, they require a larger space.

V. When there is another principle of motion besides the surcharge of the air; this proves an accessory, that increases and strengthens the principal: whence it is, that great and boisterous winds seldom arise from a bare surcharge of the air.

VI. There are four accessories to the surcharge of the air; viz. 1. Subterraneal expirations; 2. precipitation from that called the middle region of the air; 3. dissipation of formed clouds; and, 4. mobility and acrimony of the exhalation itself.

VII. The motion of the wind is almost constantly lateral: that which proceeds from the simple surcharge of the air, is so from the first; and that which proceeds from subterraneous expirations, or repercussion from above, becomes so soon after; unless when the eruption, precipitation, or reverberation, are exceedingly violent.

VIII. Air will sustain some compressure before it becomes sensible of being over-loaded, or before it will impel the air contiguous to it;

whence it is, that all winds are somewhat more dense than air at rest.

IX. Winds are allayed five ways, viz. 1. when the vapours come together, 2. incorporate, 3. sublime, 4. transport, or 5. spend themselves.

X. Vapours come together, or the atmosphere forms itself into rain, four ways, viz. 1. by being oppressed with quantity, 2. condensed by cold, 3. by contrary winds driving the vapours together, and 4. by reverberating obstacles.

XI. Both vapours and exhalations afford matter of winds: for though rain never proceeds from exhalations, yet winds may frequently proceed from vapours. But there is this difference, that the winds made from vapours more easily incorporate with pure air, become sooner appeased, and prove not so stubborn, as those from exhalations.

XII. The modification and different states of heat, have as great an effect in the production of winds, as the quantity or conditions of the matter.

XIII. In the generation of winds, the sun's heat should be so proportionate as to excite them; but not so plentifully as to make them collect, into rain; nor yet so sparingly as to make them totally disperse and dissipate.

XIV. Winds blow from the quarters of their nurseries: and when these nurseries are differ-

ently seated, different winds generally blow together; but the stronger either subdues the weaker, or turns it into its own current.

XV. Winds are generated all the way up, from the surface of the earth to the cold region of the air: but those that blow oftenest, are generated near hand, and the stronger above.

XVI. The countries which have their serving-winds warm, are hotter, and those that have them cool, are colder, than in proportion to the climate.

SECT. XVII.

A TABLE OF PARTICULARS MORE IMMEDIATELY SERVICEABLE TO MANKIND: OR DESIDERATA WITH THEIR APPROXIMATIONS; DRAWN FROM THE PRECEDING ENQUIRY.

DESIDERATUM. I. *A method of forming and disposing the sails of ships, so as with a less wind to make more way: a thing of great use for shortening voyages, and lessening their expence.*

No discovery has hitherto been made to answer this desideratum precisely in practice; but consult the larger observations under Sect. XIII.

II. To construct wind-mills, and their sails, so as that they may perform more work with less wind: which also is a matter of advantage.

Consult upon this head our experiments under Section XIII.

III. A method of predicting the rising, falling, and times of the winds: a thing of use in navigation, and agriculture; but especially in chusing the times for sea-fights.

There are many things to this purpose in the preceding enquiry, especially under Section XIV. But the observations of posterity, now the cause of winds is explained, may afford much more exact prognostics.

IV. A method of prognosticating, and forming judgment, upon other things, from the winds: for example, whether there be any other unknown continents, or islands in the sea of any place; or whether the sea be open and uninterrupted: a thing of use in navigation; and the discovery of new countries.

The approximation here, is the observation of stated winds; which seems to have been used by Columbus.

V. A method of predicting the plenty or scarcity of fruits, and corn, every year: which would be matter of profit, and regulate bargains and sales for time; as Thales, from a natural divination of this kind, is said to have bought up all the olives of his country.

There are some things to this purpose under Section VI.

VI. So likewise it would be an useful thing, and for the reputation of physicians, to predict the di-

*seases and pestilences of each year; if this could be done: as also, for discovering the causes and cures of distempers; with some other affairs of political consideration.**

And with regard to this, also, there are certain particulars in the present enquiry, especially under Section VI.

ADMONITION.

In the business of predicting plenty or scarcity of corn and fruits, and the rise of distempers by the winds; let the histories of agriculture and medicine be consulted.*

VII. A method of raising and laying the winds.

There are certain superstitious and magical relations, with regard to this matter, not worthy to be received into a serious and rigid natural history; nor can we, at present, think of an approximation. However, with a view thereto, let the nature of the air be thoroughly sifted and examined; to try whether any thing may be found, that when communicated in a small quantity to it, may excite and multiply motion; so as to dilate and contract the body of the air: for if this could be done, the raising and laying of the winds would follow of course; after the manner of Pliny's experiment, if true, of playing vinegar into a whirlwind. Another attempt might be

* See the author's New Atlantis ad finem.

† See above, the admonition at the close of Sect. XIV.

made, by letting out the winds from subterraneal places; if any were plentifully collected therein; as is currently reported of the pit in Dalmatia: but it will be difficult to discover the places wherein winds are thus imprisoned.

VIII. Ways of producing many surprizing and diverting phænomena, by the motion of the winds.

But of the methods for effecting this, we have no leisure to consider. The approximation is the common way of fighting battles by the wind.* And, doubtless, many agreeable things of this kind might be invented; both with regard to motion and sound.†

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* This is also mentioned under the thirteenth article of the table of enquiry. I suppose the author means, the school-boys diversion of fighting battles, by the flying of paper-kites.

† See the Sylva Sylvarum, under the article Sound. In order to prosecute the enquiry, it might be proper to consult, all that relates to it in the Philosophical Transactions; French Memoirs, and German Ephemerides, Sir Isaac Newton's Principia, Mr. Boyle's Philosophical Works, Stahl's Observatio Meteorologiæ Cokio-Sluterianæ, Boerhaave's four chapters upon the elements, in his Chemistry; Honoratus Faber, &c. But some of the principal matters here required, seem not hitherto received into books; and must be derived immediately from nature, the common practical arts or new experiments, purposely made to give farther light, and information, in this subject.

A

PLAN

FOR THE PARTICULAR HISTORY

OF

CONDENSATION AND RARIFACTION

IN

NATURAL BODIES.

PREFACE.

THIS is a posthumous piece, and published in the original Latin, with considerable care, by the author's chaplain and amanuensis, Dr. Rawley; that being a very imperfect edition given of it by Gruter. It is one of the six histories which the author designed to write monthly. Three of these monthly productions are extant; viz. the History of Life and Death, Winds, and the present history of Rarity and Density. But those of Sympathy and Antipathy; the three chemical principles; and of Gravity and Levity; were not published. Nor does there appear to be any thing hitherto written that may supply the want of them. But the original, from whence they were to be copied, is nature; which we have always before us.

The subject of rarifaction and condensation, has indeed been laudably prosecuted by the moderns; especially since the invention of the air-pump, and other pneumatical and hydrostatical engines and instruments. Yet it does not seem to have been pursued in all that variety and fullness, wherein it is here sketched out by the author.

An unseasonable indulgence of mathematical speculations, seems to have somewhat diverted the pursuit: for the thing appears of late, to have been rather mathematically than physically considered. So that we have had worlds made in the imagination, by the supposed rarifaction of single particles of matter; and many other such mathematical levities, or sports of fancy; whilst the full process and use of rarifaction, and condensation, in the real world, has been less attended to than it deserves. For, doubtless, a thorough knowledge of this subject would lead to a discovery of many arts and works; an instance whereof we have lately had in the discovery of that noble engine, for raising water by rarifaction, and condensation.

It may, perhaps, appear surprizing, to those who shall diligently peruse the following piece, that the author should have seen so far into the modern physics; and himself have here laid, not only the foundations of our present hydrostatics, and pneumatics, but also of much greater discoveries.

INTRODUCTION.

NO wonder if nature remain debtor to philosophy and the sciences, when she has never been summoned to an account. For there has hitherto been no careful and regular enquiry, no exact or tolerable estimate made, as to the sum or quantity of matter in nature; nor any notice taken how it is disposed, and laid out upon bodies. It is a just axiom, That nothing can be detracted from, or added to the sum total of the universe. And some, indeed, have handled the common-place, how bodies may be relaxed and contracted, in respect of more and less, without admitting a vacuum between: but for the nature of condensation and rarifaction, one attributes it to a greater and less quantity of matter; another eludes the point; whilst the generality following their author*, think to discuss and settle the whole matter by that trifling distinction of act and power. And even they who attribute condensation and rarifaction to the different quantities of matter, which is the true notion, and do not totally deprive the materia prima of quantity; though, for other forms, they require it to be indifferent, yet here end their enquiry, and look no farther; without perceiving the consequence: thus slightly passing over, or at best not fully pursuing, a consi-

* Viz. Aristotle.

deration which regards infinite particulars; and is in a manner, the foundation of all natural philosophy.

To proceed, therefore, upon what has been justly laid down in all the transmutations of bodies; matter can be annihilated; but it requires the same omnipotent power to annihilate, as to create out of nothing; neither of which ever happens in the course of nature; so that the original quantity of matter remains for ever the same, without addition or diminution. And this original stock of matter is differently portioned out among bodies, cannot be doubted; for it were madness, by abstract subtilties, to pretend, that one hogshead contains as much water as ten hogsheads of water; or, that one hogshead of air contains as much as ten hogsheads of air. But though it be admitted, that the quantity of matter rises in proportion to measure, in the same body; this is still questioned in bodies of different kinds. But if it be demonstrated, that one hogshead of water turned into air, will make ten hogsheads of air (and it may rather be proved to make a hundred) there is an end of the dispute; for in this case, the water and the air are the same body; now contained in ten hogsheads, though before it was contained in one. And therefore to assert, that one whole hogshead of water may be converted into but one whole hogshead of air, is in effect, to assert that something may be reduced to nothing: for in this case, one tenth part of the water is sufficient; and the other nine parts must then be annihilated. So, on the contrary, to assert, that a hogshead of air is convertible into a hogshead of water; is to assert that something may be created out of nothing; for the hogshead of air will make but the tenth part of a hogshead of water; and therefore the other nine parts must be produced from nothing.

We shall, however, ingeniously confess it a difficult task,

to settle and ascertain the exact proportions and quantities of matter, contained in different bodies; and to shew by what industry and sagacity a true information may be had thereof: though the great and extensive usefulness of the enquiry may abundantly reward the pains that shall be bestowed upon it. For to understand the density, and the rarity of bodies, and much more, how to procure and effect their condensation and rarifaction; is a thing of the utmost importance, both in speculative, and practical philosophy. Therefore, as the enquiry is, perhaps of all others, the most fundamental and universal; we should come to it well prepared: for all natural philosophy is a perfectly loose and untwisted thing without it*.

* The author keeps to his original design of enquiring into such subjects first, as are either most useful in themselves, or most fundamental; and leading to others.

A

PLAN

FOR THE

PARTICULAR HISTORY

OF

Condensation and Rarifaction, &c.

SECT. I.

A TABLE OF ENQUIRY FOR THE PARTICULAR HISTORY OF DENSITY AND RARITY IN NATURAL BODIES.

ARTICLE I.

Tables of Rarifaction and Condensation.

LET a table be formed, from particular experiments, to shew by inspection, the specific gravities, or different weights of all tangible bodies, under equal dimensions; with relation to gold; and explain the construction, nature, and uses of this table.

Let tables also be formed of bodies, under the same dimensions, whole, and in powder; crude and distilled; as also of pneumatical bodies, according to their degrees of expansion. The

whole of this to regard the expansion of matter in bodies; according to their different consistencies, whilst at rest.

II. *The dilatations caused by simple introsusception; or the admission of one body into the pores of another.*

If possible, let the enquiry be here diligently prosecuted about the appetites and motions of bodies, whereby they swell and sink, rarify and condense, dilate and contract, &c. because this is of great use; as, at once, serving to disclose, and govern nature. And yet it must proceed summarily; because the subject of density and rarity is so copious and general, that, if fully prosecuted, it would anticipate many of the following titles; which should not be allowed of.

III. *Dilatation of the innate spirit, expanding itself.*

Let the enquiry pass on to the dilatations and tumefactions of bodies; caused by their own internal spirit; whether naturally, or preternaturally; but without fire, or manifest external heat.

IV. *The dilatations and relaxations of bodies, by means of actual, simple, external heat.*

This enquiry properly belongs to the subjects of heat and cold, dilatation, separation, and alteration; yet some knowledge of the relaxations of bodies by fire is here necessary, for the more

commodious carrying on of the enquiry into condensation and rarifaction. Let this therefore, be touched only as in passage.

V. *Dilatations by external heat in distillations.*

The enquiry should next proceed to the dilatations and relaxations of bodies by heat in distillations; which affords a better opportunity, than coction or calcination, of discovering the exact process of this kind of relaxation: but as the prosecution hereof properly belongs to the title of heat and cold, and the motion of dilatation and separation; it should be sparingly touched under the present article, though it were otherwise useful to dwell thereon.

VI. *The dilatations and relaxations of bodies by the remission of cold.*

Let the enquiry next proceed to the dilatations and relaxations of bodies, upon the remission of violent cold; or a less comparative degree of heat; as in thawing, &c.

VII. *The dilatation and relaxation of bodies by potential heat; or the auxiliary spirits of other bodies.*

From the dilatations made by external heat, and the remission of cold; proceed to those made by potential heat; or the assisting spirits of another body applied. And as for the business of potential heat, it is proper to consult the medicinal tables of secondary qualities; from thence

to collect the things that separate by dilatation in the human body.

VIII. *The dilatation of bodies by a releasement of their spirit.*

Next proceed to the dilatation of bodies made by a releasement of their spirits; upon breaking the prisons of the grosser parts, which closely detained them; so that they could not dilate themselves.

IX. *The dilatation happening upon the meeting and uniting of bodies related.*

This kind of dilatation is, in some cases, called dissolution; though it happens without any manifest tumult. Enquire out the instances hereof.

X. *The dilatation by assimilation; or the conversion of a grosser matter to such as is more subtile.*

This is understood of an actual conversion of one body into the substance of another: the more eminent instances whereof are to be carefully collected.

XI. *Dilatations or distractions, by external force.*

These dilatations or distractions, are such as proceed not from any appetite in the dilated body; but from the violence of a body external; which prevailing, obliges the other to dilate.

XII. *Dilatations by diffusion; or spreading.*

This being a spurious kind of dilatation it need not be here very particularly enquired into:

though the more eminent instances should be enumerated; as the ductility of gold, &c.

XIII. *Contraction by the emission, or discharge, of a body received.*

Having thus prosecuted the business of dilatations, rarifactions, and relaxations of bodies; the contrary actions thereto must also be enquired into; viz. the contractions, condensations, and shuttings up of bodies. And as contraction is correlative to dilatation; that must be thoroughly examined.

XIV. *Contractions by the shrinking of the grosser parts, after the discharge of the spirits.*

Here again, the instances are to be carefully collected.

XV. *The contraction of bodies by actual, external cold.*

This is the reciprocal action to that of dilatation by external heat; and the most genuine and proper kind of contraction. Here, therefore, the enquiry should be more largely and fully prosecuted; so far as the degrees of cold, upon the earth's surface, can be made to reach.

XVI. *The contraction of bodies by potential cold.*

Let this article be prosecuted as the correlative to article VI.

XVII. *The contractions of bodies by flight, and antiperistasis.*

This is the opposite to dilatation by union and embrace. See article IX.

XVIII. *The contraction of bodies by assimilation or conversion, into a denser state.*

This is the correlative to article X.

XIX. *The contractions of bodies by external violence.*

This corresponds to article XI. *

SECT. II.

A TABLE EXPRESSING THE DENSITY AND RARITY, OR SPECIFIC GRAVITIES, OF DIFFERENT TANGIBLE BODIES, IN PROPORTION TO GOLD; WITH THE EXPLANATION, AND USES THEREOF.

The bodies in the following tables were all taken of the same bulk, or dimensions.

THE TABLE, IN ALPHABETICAL ORDER.†

Pure gold weighed an ounce, or twenty penny-weight.

	Pennyweight.	grs.		Pennyweight.	grs.
Alabaster - - -	2	12	Ashes, common -	1	0½
Alum - - - -	1	21	Balsam, Indian -	1	6
Amber - - -	1	3	Beer, strong - -	1	3½
Aqua-fortis - -	1	7	Benjamin - - -	1	0

* Fuller directions, admonitions, and precepts, are occasionally interspersed in the enquiry itself.

† For the sake of convenience, and ready use, this table is ranged in alphabetical order; though there are considerable ends answered also by disposing it in the natural order, to shew how bodies run down, in a descending scale, the most ponderous substance, gold; to the lightest

	Pennyweight.	grs.
Borage, its expressed juice	1	3½
Brass, coarse	8	9
....., fine	9	5
Brimstone	2	2
Butter	1	0
Calve's brain, raw	1	4¾
Camphire	1	4
Chalk	1	18½
China-root	1	2
Clay, common	2	8½
....., tobacco-pipe	2	5½
Copper	9	8
Crystal	2	18
Earth, common	2	1½
Ebony-wood	1	3½
Fennel-seed, powdered	1	3½
Fir-wood	0	15
Flint	2	22½
Glass	2	20½
Guaiacum-wood	1	10
Jet	1	5
Iron	8	6

	Pennyweight.	grs.
Ivory	1	21½
Lead	12	1½
Loadstone	5	12
Marble	2	22½
Marjoram, sweet, in powder	0	23
Milk, cow's	1	4½
Mint, its expressed juice	1	4
Myrrh	1	0
Nitre	2	5
Oak-wood	0	19½
Oil of sweet almonds	0	23½
..... cloves, chemical	1	3
..... mace, green, by expression	0	23½
..... sulphur	1	18
..... vitriol	1	21
Onion, fresh	1	5
Ox bone	2	5
.... horn	1	6
Pear, winter, raw	1	2
Pearl powdered	2	2

the author tried, which was fir. Whence, we judge, that both forms ought to be preserved; at least till a complete table of the specific gravities of all bodies is procured; though on many occasions, even then, it would be proper to have two; one in the order of nature, and the other in that of the alphabet, according to the present example.

	Pennyweight.	grs.
Petreol	0	23
Quicksilver	19	9
Rose flowers powdered	0	22
Rose-water distilled	1	1
Sal-gem	2	10
Salt, common, in powder	1	10
Sand, white	1	20
Saunders, red	1	5
Sheep's blood	1	5
..... flesh	1	10
Silver, pure	10	21
Soot, common, from the chimney, in powder	0	17

	Pennyweight.	grs.
Spirit of wine	0	22
Steel	8	10
Suet	1	0
Sugar, white, powdered	1	2½
Tin, block	7	22
Tin-glass	10	12
Touchstone	3	1
Verjuice of crabs	1	3
Vinegar	1	3½
.... distilled	1	1
Vitriol, white	1	22
Urine, common	1	3
Water	1	3
Wax, yellow	1	2
Wine, claret	1	2¾

THE SAME TABLE IN THE ORDER OF NATURE.

	Pennyweight.	grs.
Pure gold	20	0
Quicksilver	19	9
Lead	12	1½
Pure silver	10	21
Tin-glass	10	12
Copper	9	8
Fine brass	9	5
Steel	8	10
Common brass	8	9
Iron	8	6
Block-tin	7	22
Loadstone	5	12
Touchstone	3	1

	Pennyweight.	grs.
Marble	2	22¾
Flint	2	22½
Glass	2	20½
Crystal	2	18
Alabaster	2	12
Sal-gem	2	10
Common clay	2	8½
Tobacco-pipe-clay	2	5½
Nitre	2	5
Ox bone	2	5
Powdered pearl	2	2
Brimstone	2	2
Common earth	2	1½

	Pennyweight.	grs.
White vitriol	1	22
Ivory	1	21½
Alum	1	21
Oil of vitriol	1	20
White sand	1	21
Chalk	1	18½
Oil of sulphur	1	18
Common salt, in powder	1	10
Guaiacum-wood	1	10
Sheep's-flesh	1	10
Aqua-fortis	1	7
Ox horn	1	6
Indian balsam	1	6
Calve's brain, raw	1	5¾
Sheep's blood	1	5
Red saunders	1	5
Jet	1	5
Fresh onion	1	5
Cow's milk	1	4½
Camphire	1	4
Mint, its expressed juice	1	4
Borage, its expressed juice	1	3½
Strong-beer	1	3½
Ebony-wood	1	3½
Fennel-seed, powdered	1	3½
Vinegar	1	3½
Verjuice of crabs	1	3
Shining amber	1	3

	Pennyweight.	grs.
Urine	1	3
Common water	1	3
Oil of cloves, chemical	1	3
Claret wine	1	2¾
White sugar, powdered	1	2½
Yellow wax	1	2
China-root	1	2
Winter-pear, raw	1	2
Vinegar, distilled	1	1
Rose-water, distilled	1	1
Common ashes	1	0½
Myrrh	1	0
Benjamin	1	0
Butter	1	0
Suet	1	0
Oil of sweet almonds	0	23½
Oil of mace, green, by expression	0	23½
Marjoram, sweet, in powder	0	23
Petreol	0	23
Rose flowers, powdered	0	22
Spirit of wine	0	22
Oak-wood	0	19½
Soot, common, from the chimney, in powder	0	17
Fir-wood	0	15

THE CONSTRUCTION, NATURE, AND USE OF THE PRECEDING TABLE.

THE weights made use of are the common ones of the gold-smith; the pound consisting of twelve ounces; the ounce of twenty-penny weight; and the penny weight of twenty-four grains. We make choice of pure gold for the standard, and adjust the dimensions of the other bodies thereto; because this is not only the heaviest substance we know; but also the most uniform, homogeneous, and without any volatile part. The experiments, upon which the table was formed, proceeded thus.

We fashioned an ounce of pure gold into a solid cube, and provided a square case, or box of silver, which contained and fitted it exactly; excepting only, that the case rose somewhat higher: but a line was drawn on the inside of it, at the precise height whereto the gold cube reached. This we did for the convenience of filling the case with fluids, and powders; so that when either of them were put in, they might not run over, or be spilt; but contain themselves level within. We likewise provided another similar case, perfectly of the same weight and dimensions; in order to shew the proportion which the body, contained in one, bore to that 'ained in the other. Then cutting cubes

of the same dimensions, or bulk, with that of the gold, in all the solid bodies specified in the table which would bear cutting, we fitted them exactly into the cases, up to the line; and poured in our liquors to the same height occasionally. The like we also did by the powders; constantly observing to squeeze and press them in so strong, that they might lie even and uniform, without subjecting our experiments to casualty.

Then for the trials themselves; we put one of the cases, empty, in one scale, and the other case, containing the body to be examined, into the other scale of the balance; and separately took the exact weight of each body so contained. For, as much as the weight of the body fell short of that of the gold; so much the bulk of the body exceeded that of the gold. Thus, for example, as the gold cube weighed an ounce, and an equal cube of myrrh, weighed but one penny-weight; it follows, that the bulk of myrrh is to the bulk of gold, as twenty to one: so that there is twenty times as much matter contained in gold as in an equal bulk, or dimension, of myrrh; or, again, twenty times as much bulk, or distention in myrrh, as in an equal weight of gold.

ADMONITIONS.

1. The vessel here employed, would not, on account of its smallness and figure, allow the

experiments to be made with any great exactness: by its means we could not easily take the specific gravities below a quarter of a grain; and the little square surface of the matter, might by a small and insensible rising, make some difference: so that vessels rising sharp and conical, are best suited for forming an accurate table of this kind*.

2. No doubt but many of the bodies expressed in the foregoing table, have a greater or less specific gravity than others of the same kind; so that one wine would contain more matter in the same space, than another; and one wood more than another wood of the same species, &c. And therefore the business of exact trials, and settling the accurate proportions of the specific gravities of bodies, is here somewhat uncertain, or casual. Nor can it be expected that the individual bodies we made our experiments with, should be a standard of the nature and gravity of each species; or that they should perfectly agree with the experiments made by others, in the same manner†.

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* As in M. Homberg's glass for taking the specific gravities of liquors; where a single drop is made to possess a considerably long space in the slender graduated neck.

* To this may be added the different seasons of the year, and times of the day; as to heat and cold, dryness, and

3. We have received into our table, only such bodies as would commodiously occupy and fill up space; whilst the body remained as it were entire, uniform, and similar: and such also as have a sensible gravity in the air; from which gravity we might judge of their quantity of matter. So that there are three kinds of bodies whereto our experiments were not applied; viz. 1. those that are uncapable of a cubical dimension; as leaves, flowers, pellicules, membranes, &c. 2. such as are unequally porous and cavernous; as sponge, cork, wool, &c. And 3. untangible bodies, whose weight is not perceived in the air; as flame, air itself, &c.*

4. Enquiry should be made, whether, possibly, the close contraction or condensation, of a body, by an uniform force on all sides, will give it a greater proportion of gravity, than corresponds to its quantity of matter. This enquiry belongs to the particular history of gravity†: and if it terminate in the affirmative, our calculation must needs be erroneous; and the more rarified

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moisture, &c. All which occasion variations in very curious experiments of this kind.

* These experiments require the assistance of the air-pump.

† This history the author intended to write; but it was not published.

any body is, it will contain somewhat more matter under the same bulk, than is assigned it by our method*.

This table I made many years since; though, as far as I remember, with tolerable care and exactness: but, doubtless, an infinitely more accurate one may be formed, from trying a greater number of bodies, and in larger quantities; which greatly contributes to render the experiments more just. And this being a fundamental thing in philosophy, it should by all means be procured†.

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* This point may now seem settled, by the industry of the moderns; since it is shewn, by experiment, that quantity of matter and absolute gravity are reciprocal; or that the matter in bodies corresponds exactly to their weight. The question here turns upon the distinction betwixt absolute and relative, or specific gravity. Absolute gravity is the weight of bodies in a perfect vacuum, or unresisting medium: and relative gravity, their weight in a resisting medium; which lessens the absolute gravity of a body, in proportion to the density of the medium. So that the same body weighs less in air than in vacuo; less in water than in air, &c. Therefore, in the present case, where the experiments are made in the air; the condensation of a body, by lessening its surface, will cause it to be less resisted by the air; and consequently to weigh the more. But in an absolute vacuum, the same body ever so much condensed. weighs no more than the same body ever so much expanded

† There are several tables of this kind extant; though none perhaps so copious and extant as is on many occasions

LARGER OBSERVATIONS.

1. It is an agreeable prospect to see, from such a table as this, how finite and comprehensible the nature of tangible bodies is; for such a table grasps, as it were, all natural bodies in the hand. And let no man here indulge his fancy, or his levity; but consult experience: for our table shews, that there is no tangible body in nature exceeding another in quantity of matter, above thirty-two to one; which is the proportion wherein gold exceeds fir-wood. As for bodies near the centre of the earth, we can say nothing to them; since they neither come under our senses nor experience: possibly, as they lie very remote from the heat of the celestial bodies, and are quite cut off from any communication therewith; they may be more dense than any of the bodies we know.

2. There can be little justness in that opinion, which supposes sublunary bodies composed of the four elements. For our cubical lump of gold in the table, was twenty penny-weight; whereas common earth is little more than two; water but one and three grains; and air and fire are still vastly more rarified, as being not

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required. See Mr. Boyle's piece of Hydrostatics applied to Ores and the Materia Medica; and for the uses of such a table, see hereafter.

tangible, and insensible upon the balance: and form does not increase the matter of bodies. It must, therefore, on this footing, be considered, which way a body of twenty penny-weight, can by form be produced, under equal dimensions, from a body of two penny-weight; and from others vastly more rarified. There are here two subterfuges; the one, that the more rarified elements squeeze the denser to a greater closeness than the simple element itself: the other, that the peripatetics do not understand this of common, but of elementary earth; which is heavier than any compound substance. But fire and air do not condense bodies, except by accident; as we shall shew hereafter. And for the earth, which should be heavier than gold, and all other bodies; it is so buried, as hardly to be found, and employed in mixture.* It were, therefore, much better for the Peripatetics to leave off trifling, and dictating in philosophy.

3. The scale of density in bodies, or the degrees wherein they fall from a closer texture of matter, to a looser, should be carefully noted; and how this sometimes happens by smaller steps, and sometimes by larger strides: such a view being of service, not only to inform the judgment, but also in leading to practice. The

* See Mr. Boyle's Sceptical Chemist.

density of metalline bodies is the greatest; and runs eleven steps downwards, from gold to tin; proceeding by a large start from gold and quicksilver, to lead; but gradually, or slowly, from lead to tin. Again; there is a great leap from metals to stones; only the loadstone comes in between; which is thence proved to be of metallic nature.* But from stones to all other bodies, there is a continued, regular, and slow descent.

PRECEPT.

1. As the seat of density may seem to be in the depth of the earth; so the bodies towards its surface should be considerably rarified: but it is very remarkable, that gold, the heaviest of metals, should sometimes be found, nearly in a pure state, among the sand and gravel of rivers. A careful enquiry should be made into the situation of such places; to discover whether they lie not near the foot, or below the bottom of certain mountains, or deep mines, from whence the gold may be washed: or otherwise, what it is that procures so great a degree of density, near the surface of the earth†.

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* Such particulars as these are frequently taken for late discoveries.

† The former is generally allowed to be the case; viz. that gold is washed down into rivers, from mines that lie

2. It should also be enquired, as to mines in general, what kind of them lie the deepest, and what nearest the surface of the earth; in what situation of a country, and in what kind of glebe or soil; how they lie with respect to the waters; but particularly in what beds; and how they are surrounded, or mixed in with stone, or other fossil matters. In short, all the circumstances belonging to them should be examined; in order to find out by what means the juices and spirits of the earth are compacted, and condensed into a metalline nature, so much heavier than that of other bodies.*

LARGER OBSERVATIONS.

1. No doubt but there are many bodies to be found, both in vegetables and the parts of animals, much lighter than fir-wood; for, we conceive that the downs of some plants, the wings of flies, the skins of snakes, and various matters treated or produced by art: such as tinder, dry rose-leaves remaining after distillation, &c. are not so heavy as the lightest woods.†

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higher: yet the question still remains, whence has gold its density; being often found in mines not far below the earth's surface?

* See the heads of this enquiry in the Philosophical Transactions; or in Mr. Boyle's works, Abridg. vol. viii.

† See Dr. Hook's Micrographia passim.

2. That erroneous notion, to which the human understanding readily inclines, in supposing hard bodies the densest, should be corrected and restrained: for quicksilver runs, and gold and lead are soft; yet these are denser and heavier than the hardest metals, iron and copper; and much denser than stones.

3. Our table of specific gravities, shews many things contrary to expectation; as that metals are much heavier than stones; glass, a factitious body, heavier than chrystal; that common earth is considerably light; that the oils, or distilled liquors of vitriol and sulphur, are almost as heavy as crude vitriol or sulphur; that the difference between the gravity of water and wine is not great; that some chemical oils, which should seem lighter, are yet heavier than oils by expression; that bone is much heavier than horn or teeth: with several particulars to the same effect.

PRECEPT.

The nature of density and rarity, though it runs through nearly all other natures, without being subject to their laws; yet seems to have a great consent with gravity and levity.* We also suspect it may have an agreement with the slow and quick admission, and rejection, of heat

* It is now generally esteemed reciprocal thereto.

and cold. We would, therefore, have trial made, whether rare bodies do not grow hot and cold, quicker than dense ones. The experiment should be performed on gold, lead, stone, wood, &c. with the same degree of heat, the same quantity, and the same figure of the body.*

PRACTICAL HINTS.

All the mixtures of bodies may be discovered by means of an exact table of specific gravities, and the test of weight. Thus to find what proportion of water is mixed with wine; lead, with gold, &c. the mixture being weighed, and the table consulted, for the respective weights of the simples; the mean proportion of the compound, compared with the simples, will give the quantity of the mixture. And this we judge was the method used by Archimedes, in detecting the debasement of king Hiero's crown.

The making of artificial gold, or the transmutation of metals into gold, should be held suspect; for gold is the heaviest and densest of all bodies; and therefore to convert any thing else into it, is absolutely the work of condensation: but condensation can scarce be super-induced by

† There are some experiments to this purpose in Boerhaave's Chemistry; particularly in the Chapter of Fire.

men upon the surface of the earth; especially in bodies that are full of matter as metals are. For most condensations effected by fire, are false, or imperfect condensations, with regard to the whole; and only condense bodies in certain parts, as we shall see hereafter.

3. But the conversion of quicksilver, or lead, into silver, which is a rarer body than either, may rationally be hoped for: as requiring only fixation, not condensation.

4. Yet if quicksilver, lead, or any other metal, could be turned into gold, in all other properties except gravity; or be rendered more fixed, more malleable, soft ductile, durable, bright, yellow; or less subject to tarnish; it may doubtless prove an useful and gainful operation.

A LARGER OBSERVATION.

We know of nothing heavier than pure gold; nor has any method yet been found of increasing the gravity of pure gold, by art*.

HISTORY.

But lead has been observed to increase both in bulk and weight; especially by lying in cellars under ground, where bodies readily grow mouldy. This has principally been observed

* The gravity of silver is said to have been considerably increased.

in stone statues; the feet whereof when fastened together with bands of lead, that have been found swelled; so that some parts thereof hung prominent, or pendulous, like warts upon the stone. But whether this were really an increase of the lead, or only a sprouting of its vitriol, should be farther examined.*

A Table, shewing the different expansion of Bodies whole and in powder.

	penny-weight	gr.		penny-weight	gr.
The cubic vessel of Crude-mercury	19	9	The cubic vessel of the close powder of Mercury Sublimate	3	22
Lead	12	1½	Ceruse	3	8⅓
Steel	8	10	Crocus Martis	2	9
Crystal	2	18	Crystal, ground	2	20
Red Saunders	1	5	Red Saunders, ground	0	16½
Oak-wood	0	19½	Oak-ashes	1	2

A Table to shew the different expansions of Bodies crude and distilled.

	penny-weight	gr.		penny-weight	gr.
Crude Sulphur	2	2	Oil of Sulphur	1	18
Vitriol	1	22	Oil of Vitriol	1	21
Wine	1	2¾	Spirit of Wine	0	22
Vinegar	1	3½	Distilled Vinegar	1	1

* See Mr. Boyle's works, abridgm. vol. iii.

ADMONITION.

The manner of reducing a body to powder, contributes greatly to the opening, rarifying, or expanding of that body. But the reduction of a body to powder by simple triture, or by filing, is one thing; by chemical sublimation another; by corrosion with acid spirits, another; and by calcination, another, so as to have very different effects.

PRECEPT.

These two tables are extremely scanty and defective; but that would be an exact and copious one of bodies and their expansions, which in the first column contained the weight of each body; in the second the weight of its crude powder; in the third, that of its ashes, calx, or rust; in the fourth, that of its pappy mass; in the fifth, that of its vitrification, if it be vitrifiable; in the sixth, its matter by distillation; in the seventh that of its solution, subducting the weight of liquor that dissolves it; and so on, till it exhibits the weights of the same body under all its changes, and other alterations: from which table a judgment might be formed of the relaxations of bodies, and the closest integral connexions of nature.

OBSERVATIONS.

Pulverization is not properly a rarifaction of the body pulverized; because the increase of

bulk proceeds not from the dilatation of the body; but from the interposition of air: yet an estimate of the internal connexion or porosity of bodies may be excellently derived from it. For the closer bodies unite, the greater difference there is between their powder and entire body; and therefore quicksilver is to mercury-sublimate in powder, as above five to one; and the proportions of steel and lead to prepared steel, and ceruse in powder, are not so much as four to one. But in the lighter and more porous bodies, there is sometimes a looser position of parts, in the wholes, than in the pressed powders; so the ashes of oak-wood are heavier than oak itself. And again, in powders, the heavier the entire body is, the less dimension its squeezed powder has, in comparison of another unsqueezed: for in light bodies the parts of powders may sustain or support themselves; so that an unsqueezed powder shall possess thrice the space of a squeezed one; on account of its less condensing, and dividing the air interposed betwixt its parts.

2. Distilled bodies are generally rarified, and made light, by the operation; but wine twice more than vinegar.

A speculation for practice.

And thus tangible bodies may be reduced under classes, according to their families; or as

they prove rich or poor in matter. But there is another class of things which we call pneumatical, or untangible; so that not being subject to the balance, no judgment can be formed of the distention or rarification of the matter they contain. Whence this affair requires another kind of interpretation. But first; the several species of pneumatical bodies are to be laid down; that they may be compared with each other. But as in the case of tangible bodies, we for a time postpone the consideration of the internal parts of the earth; so in the case of pneumatical bodies, we postpone for a time, those that are ethereal.

We range pneumatical bodies under three general classes; viz. 1. The imperfect; 2. the confined; and 3. the pure. 1. The imperfect are, fumes of all kinds, proceeding from different matters. These may stand in this order; 1. Volatile fumes that breathe out from metals and some other fossils; being, as their name imports, rather volatile than pneumatical; and very easily coagulated either by sublimation or precipitation. 2. Vaporous fumes, expiring from water and aqueous bodies. 3. Under the general name of fumes, we likewise include the expirations of dry bodies. 4. Exhalations proceeding from oily bodies. 5. Breaths afforded by bodies aqueous in their substance, but inflammable in

their spirit; as in wines, and other fermented spirituous liquors.

There is also another kind of fumes in which flame terminates; and such as expire only from inflammable bodies, consequent to the flame: and these we call after-fumes, or secondary-fumes. So that there can be no after-vapours, because aqueous bodies are uninflammable; but there may be after-fumes, in our particular sense, as also after-exhalations, after-breaths, and probably after-volatile parts in some bodies.

2. But confined pneumatical bodies are those found, not independent or free, but included in tangible bodies; and are what we commonly call spirits. These participate both of an aqueous and oily substance; and are nourished and fed thereby: and being converted into a pneumatical substance, they constitute a body, as it were consisting of air and flame; and thence produce the strange effects of both*. These spirits, with regard to pneumatical bodies that are free and at large, nearly approach to the nature of breaths; such as arise from wine, &c. And these spirits are of two kinds; the one of crude, and the other of living bodies. The crude spirits are contained in all tangible bodies; but the living

* See the axioms at the end of the History of Life and Death.

spirit only in such as are animated, whether of the vegetable or sensitive kingdom. 3. But there are no more than two pure pneumatical bodies, viz. air and flame: though these also are subject to great diversity, and receive very unequal degrees of extension.

A Table of pneumatical bodies; conformable to the preceding speculation; as they receive in order, a greater degree of extension.

The volatile parts of metals and fossils.
The after-volatile parts of the same.
Vapours.
Fumes.
After-fumes.
Exhalations.
After-exhalations.
Breaths.
After-breaths.
Crude spirits, confined in tangible bodies.
Air.
Living spirit, confined in tangible bodies.
Flame.

We are next to consider the respective extensions of these pneumatical bodies; as well with regard to themselves, as to tangible bodies. And here it might be well, if the nature of levity, by an ascending scale, would elucidate and correspond to the rarifaction of bodies; as the nature

of gravity, by a descending scale, does to their density. But several difficulties interpose: as first, that the differences of motions in objects invisible, are not immediately perceived by the senses. Secondly, that in air, and the like substances, there is not found so strong an appetite of moving upwards, as men imagine. And lastly, if the air did move upwards: yet it is generally continued along with other air, the motion would be difficultly perceived. For as water does not preponderate in water; so air does not rise up against, and displace air. And therefore other methods must be invented.

There are certain considerable proofs of the proportionate expansions of pneumatical bodies, with regard to each other; shewing also at the same time, that the series of rarifaction expressed in the table, has a solid foundation: but for the precise degrees of this expansion, and the comparative expansion of a pneumatical with a tangible body, the enquiry is more difficult.

All fumes, whether primary or secondary, do not, it is highly probable, come up to the rarity of the air; they being visible; but the air invisible: nor do they themselves remain visible after being mixed along with the air.

It is manifest that after-fumes are more subtile, and rarified, than fore-fumes; as being no other than the calxe's and resolutions of that

subtile body flame itself. And so it appears from experience, that though the numerous lights continue for a long time burning in a room, or large assembly, the air is not thereby unfitted for respiration; notwithstanding so many after-fumes are received into it: but if the lights were to be extinguished, and their fore-fumes, or fuliginous steams, to be received instead of the former; the air would soon prove suffocating to the company.

We likewise judge that all crude spirits confined in tangible bodies, are denser than air: for the spirits of vegetables, dead creatures, or the like, do, upon their exhalation, manifestly detain some gross, or tangible parts; as appears from odours; which being nothing but fumes going out sparingly, and a little at a time: (as we see in such fumes and vapours as are visible;) yet if they meet with any suitable, or soft, tangible body, they apply themselves to it, stick therein and communicate their odour: whence, it is plain, that they obstinately retain an affinity with gross bodies.

But we conceive living spirits to be somewhat rarer than air; because they are a little like flame*; and again because upon careful experi-

* See the axioms at the end of the History of Life and Death.

ence, we have found that air has no power to diminish weight; for a blown bladder is not lighter than an empty and compressed one; nor is a sponge or a fleece of wool full of air, lighter than the same when empty, or with the air squeezed out. But the bodies of animals differ sensibly in their gravity before and after death: though not so much as is commonly conceived.* Therefore air seems not at all to diminish gravity; as the living spirit appears to do: and as weight is the criterion of density; so the diminution of weight should be the criterion of rarity.†

Flame comes last in this series; because flame manifestly ascends: and again, because the na-

* It should seem as if the author had made some experiments about the weight of animal bodies alive and dead; and that these experiments did not agree with those of Mr. Boyle; who upon weighing a live mouse and a kitten, then strangling them, and immediately weighing them again, found them a little lighter. See Abridgm. Vol. II. p. 527. This matter requires to be farther prosecuted; and at the same time it should be fully tried, whether eggs gain in weight upon their animation.

† Let the distinction of specific and absolute gravity, be well remembered; and that in common weighing, the experiment is made in a gravitating fluid. Thus if the body collapse, or shrink, after death, it might when weighed in air, prove heavier upon the balance, than when alive. This affair seems subject to many contingencies: and it requires caution to make a valid experiment therein.

tures of pneumatical bodies differ not from those of the tangible bodies that supply them. And, therefore, as oil is rarer than water; so flame should be rarer than air, and spirit. Again, flame seems to be a thinner, softer, and more yielding body than air; since the lightest commotion of the air near a burning taper, will cause the flame to tremble.

HISTORY.

How great soever the difficulty might be of discovering the expansion of a pneumatical, with regard to a tangible body; yet we have not despaired thereof: and it seems to us a very certain kind of proof, if any tangible body of a known expansion, could be converted into a pneumatical body: and then the expansion of that be likewise observed; so as, from a comparison of the two proportions, an evident demonstration might be had of the dimensions upon the rarifaction.

We, therefore, took a small glass vial, capable of containing about an ounce; and poured into it half an ounce of spirit of wine; which being the lightest of liquors, comes nearest to a pneumatical nature: then taking a new and large bladder, capable of containing a gallon, and squeezing all the air out of it, as exactly as possible, till the sides came close together; and also rubbing its outside well with oil, to make it still

more close and pliable; we tied its neck tight, over the mouth of the vial, with a wax thread. We now placed the vial over warm embers in a chaffing-dish; when presently the vapour of the spirit of wine ascended into the bladder: and strongly inflated it every way. Then immediately removing the glass from the fire, and pricking a hole in the top of the bladder, that the vapour might rather get out, than fall back into drops; we took the bladder away from the vial, and examined by the balance what proportion of the half ounce of spirit was wanting, or turned into vapour; and found it to be not more than six pennyweight: so that six pennyweight of spirit of wine, which in that state did not possess above one fortieth part of a pint, being turned into vapour occupied the space of eight pints.

ADMONITION.

The bladder began to grow somewhat flaccid upon being removed from the fire; so that notwithstanding such a considerable expansion; the vapour did not seem converted into a pure and fixed pneumatical body; but inclined to recover itself. And this experiment may prove fallacious, if it be hence conjectured that common air is still rarer than this kind of vapour; because we conceive that spirit of wine turned pneumatical, though but imperfectly, does, by reason of the heat, exceed the rarity of cold air; as air it-

self is by heat dilated very considerably, and greatly exceeds the expansion of cold air. Whence we judge that if the experiment were made with water, the degree of expansion would be much less: though the body of the water contained more matter than spirit of wine.

HISTORY.

If the fume proceeding from a wax-taper, newly put out, be viewed, and an estimate be formed of its dimensions by the eye; and again, if the body of the fume be afterwards set on fire, the expansion of the flame will appear to exceed that of the fume, as about two to one.

ADMONITION.

A few corns of gunpowder being set on fire, there appears to be a great expansion made, with respect to the body of the powder; though when the flame is extinguished, the body of the fume expands itself much more. But let it not hence be supposed, as if the tangible body were more expanded in fume than in flame; the reason of the phenomenon being this; that flame is an entire body, but fume a body mixed with a much larger portion of air: and therefore, as a little saffron tinges a large quantity of water, so a little fume diffuses itself in a large proportion of air. For a thick, dense fume, not diffused, appears less than the body of flame; as we before observed.

HISTORY.

A piece of fresh orange-peel being suddenly squeezed betwixt the fingers, and directed to the flame of a candle, there starts out a dewy, oily, aromatic matter, in fine drops, that makes a very large body of flame, in respect of those little drops.

A LARGER OBSERVATION.

Peripatetical fiction, as to the rarity of the elements being in a tenfold proportion to one another, is arbitrary and hypothetical: for it is certain that air is, at least, a hundred times rarer than water; and flame a hundred times rarer than oil; and that flame is, at least, ten times rarer than air.

ADMONITION.

This enquiry and speculation, about pneumatical bodies, should not be thought too subtile or too curious; because it is certain that an omission, and want of attending to it, has stupefied both philosophy and medicine; and rendered them, as it were, planet-struck in the true investigation of causes: whilst they have unprofitably attributed those things to qualities, which are owing to spirits.* And so much for the enquiry into the expansion of matter in bodies, according to their different consistencies, whilst at rest.

* See the axioms to the History of Life and Death.

SECT. II.

OF DILATATIONS CAUSED BY SIMPLE INTROSUSCEPTION, OR THE ADMISSION OF ONE BODY INTO THE PORES OF ANOTHER.

ADMONITION.

It would not have been difficult for us, to have reduced the following scattered history, to a better order, and method; and to have ranged similar instances by themselves: but we avoided this exactness for two reasons; first, because many of the instances are of a doubtful nature, and bear relation to several things: whence an exact method, in this case, would either cause repetition, or be apt to deceive. Secondly, the principal reason of our rejecting an exact method at present is, because we would have the work lye open to every man's industry and imitation. But if this collection of instances should have been disposed in any artificial, and extraordinary method; many, doubtless, would have despaired of performing any thing equal to this enquiry. We, therefore, direct, both by our own example and admonition, that every one in procuring and proposing instances, would use his own judgment, memory, and convenience. It is sufficient to

have the enquiry proceed by writing, and not by memory, (which indeed would be ridiculous, in such a multitude of instances,) so that it may be afterwards brought to perfection by the light of induction.* And it must be well remembered, that in this work, we only collect alms and tribute from the senses, for the treasury of the sciences; without proposing examples for the illustration of axioms; but endeavouring after experiments for the formation of axioms. We shall not, however, be wholly regardless of all arrangement in our instances, but place them so as they may afford light to each other.

UNCONNECTED HISTORY.

No wonder if the dilatation of a body ensues upon the introsusception of another body; since this is plainly an augmentation or addition; though not a genuine rarifaction. But where the body, thus received within the pores of another, is of the pneumatical kind; as air or spirit; or if it be a tangible body, that slides gradually in, and slowly insinuates itself; this is commonly

* The directions and examples delivered in the second part of the Novum Organum, should be well remembered through the course of the author's particular enquiries; as being what himself had a constant regard to. And we are persuaded, that one half of the use and excellence of his enquiries, is not perceived by the generality of readers, for want of attending to this intimation.

accounted rather a tumefaction than an addition.

Tensile or extendible bodies, as bladders, bellows, &c. are inflated and distended by the entire body of the air; so as to become hard, and capable of being struck, tossed, and projected. And a bubble of water is like a bladder; but for its fragility and tenderness.

Liquors poured from on high, out of one vessel into another, or strongly agitated with a spoon, the wind, the breath, &c. are mixed in along with the air; and thus raised into froth: but soon afterwards, they subside and shrink into less space; the air escaping again, as the little bubbles of the froth break away.

Children, for diversion, make castles of bubbles, by blowing with a pipe into soapy water; which thus becoming somewhat tenacious, a very small quantity of water is made to possess a large space, by the air received within it.

But it is not found that flame can thus be mixed, and made frothy with air, by the inflation of bellows, or other external agitation; so as to constitute a mixed body of flame and air, like to froth; which is a mixture of air and liquor.

On the contrary, it is certain that by internal mixture in a body, before it is set on fire, a mixed body may be made of air and flame: for gun-

powder has uninflammable parts from the nitre, and, its inflammable parts principally from the sulphur; whence the flame of gunpowder becomes whiter or paler than other flames;* the* that of sulphur alone be bluish; insomuch that the flame of gunpowder may be justly compared to a most expansive froth, or a kind of a fiery wind, composed of flame and air.†

But as froth is a body compounded of air and liquor, so are all powders composed of air and the small parts of the pulverized body; whence they differ from froths, only as contiguous differ from continuous bodies. For the great bulk of them is caused by the air; which distends, or sets the parts of the body at a distance; as appears from the second and third table above laid down.‡

There are tumefactions in the bellies, and other parts of animals, arising from flatulency, and an aqueous humour collected within; as in the case of the tympany, dropsy, and the like.

* Except that of camphire, and certain artificial mixtures, as in the compositions of the stars for sky-rockets, &c.

† The more intimately the thing is considered, or rather, the more experiments are made to give a proper information therein; as by the analysis of nitre, gunpowder, &c. the more just the comparison may, perhaps, appear.

‡ Sect. I.

There is a kind of pigeon, which shrinking its head within its neck, pouts and swells considerably.

In the action of respiration, the lungs alternately expand and contract, while they receive and discharge the air, like a pair of bellows.

The breasts of pregnant females swell, and grow turgid, from the milky humour contained within them.

The penis of the male is greatly dilated, in bulk, upon erection.

Observe the breadth of the pupilla of either eye in a looking-glass, then close the other eye; and you will perceive the pupilla of the open eye manifestly dilated: the spirits that served for both eyes, now flowing into one.

The cracks and fissures of bowls, and the like materials of wood, being contracted by dryness, are filled up and consolidated, by lying for awhile in water; and receiving it within their pores.

There is a kind of fungus growing upon a tree, and called by the name of jews-ears, that being put into water swells exceedingly;* which wool and sponge do not.† And so much for the intro-

* Especially if boiled in water; where they swell to five or six times their own dimensions, when dry.

† Let the number of these instances be augmented.

susception of a different body; which is, in reality, but a false kind of rarifaction.

SECT. III.

OF THE DILATATIONS PROCEEDING FROM THE INNATE SPIRIT, EXPANDING ITSELF.

TRANSITION.

We pass on to the dilatations and tumefactions made in bodies, by their innate spirit; whether these tumefactions and dilatations be natural, or preternatural, as they are called; yet, without fire, or manifest external heat: though in these cases also there may sometimes follow an addition, or introsusception of moisture, besides the simple dilatation itself.

Most new wines, or other fermenting liquors, when put up into the cask, swell and rise considerably, so as to burst the vessel, unless they get vent: and when vent is given, they heave and froth over, as if it were by ebullition.

Spirituous liquors being close confined, or hard stopt down in bottles, often burst them with a great force; and sometimes throw out the cork, or stopple, almost like a bullet out of a gun.

The seeds of plants, as of peas, beans, &c.

are observed to swell a little, before they strike root, or shoot into a stem.

Trees swelling with their native juice and spirit, sometimes burst their bark, and thence discharge gum and tears.

Many of the gems seem to be eruptions of pure juices, strained through the rocks: for both gums and gems appear, from their transparency and splendor, to be strained and depurated juices; so that even rocks and stones may swell with their native spirit.*

And no doubt, but in the sperm of animals, in the first act towards vivification there is a certain expansion of the mass.

Vitriol shoots out an efflorescence, and sprouts or grows, almost like a tree.†

Stones, with time and age, shoot out a salt, especially in moist places, that resembles nitre. ‡

All glebe-earth swells with nitre; for any kind of ground that remains covered, and heaped up, so that its juice shall neither be exhausted by the

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* See Mr. Boyle of the Origin and Virtues of Gems.

† Particularly the artificial vitriols of silver, and iron, as we see very remarkably in the Arbor Dianæ, and Arbor Martis, as they are called. See several curious papers upon this subject in the French Memoirs.

‡ Of this see Glauber in his Prosperity of Germany; and Stubbs's Answer to Henshaw's History of Nitre. Consider also of the isicles in wine-vaults, &c.

sun and air, nor consumed in the growing of vegetables, will collect nitre, as an internal tumefaction. Hence in certain parts of Europe they make artificial mines of this salt, by preserving and storing up earth in houses prepared for the purpose, and excluding the rays of the sun.*

Sweat, in animals, proceeds from a dilatation of the spirits; and, as it were a liquefaction of the juices, by motion.

The pulse of the heart and arteries, in animals, proceeds from the never-ceasing and alternate dilatation and contraction of the spirits.†

So, likewise, the voluntary motion of animals, which in the more perfect kinds of creatures, is performed by means of the nerves, seems to have its foundation, first in the compression, and then in the relaxation of the spirits.

A tumor follows upon the contusion of any limb, in animals; and frequently also upon pains.

The stinging of wasps and bees, produces a large tumefaction, in proportion to the wound;

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* See M. Lemery's two Papers of the Origin of Nitre, in the French Memoirs; and compare them with the account of Glauber.

† Let this be carefully compared with what is delivered relating to the same purpose in the author's History of Life and Death.

but the bite of a viper does this in a still greater degree.

Nettles, bryony, and the like, raise the skin, and cause blisters upon it.

The swelling of the face, or body, is accounted an evident sign of poison; especially of that kind which operates by a malignant quality, and not by corrosion.

In the common blisters made by cantharides, there arises a watery humour, or ichor, which flows out upon pricking or cutting of the skin.

All pustules proceeding from an internal cause, and the like eruptions, and impostumations, bring on apparent tumours, and raise the skin*.

Sudden anger, in some, inflates the cheeks; so likewise does pride and haughtiness.

The bodies of the frog and toad are subject to tumefaction; and many other animals, in the way of fierceness, brustle up their combs, hair, or feathers; from a contraction of the skin, by means of a swelling of the spirits.

Turkey-cocks swell themselves greatly, and brustle up their feathers astrut. And birds, while they sleep, have their bodies somewhat

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* As in the small pox, &c. here also might be mentioned the swelling of the tongue and head upon salivation.

tumid; the spirit being then dilated by the natural heat of the internal parts.

The native spirits of a body begin to swell, in all cases of rottenness, and putrefaction; when these spirits hastening to come forth, dissolve and alter the texture of the body: and if its structure be somewhat viscous and tenacious, so as to prohibit their exit, they contribute to the production of new forms; and then generate insects, worms, &c. but the origin of this act is, from the dilatation of the spirits†.

Nor does the spirit, confined in putrefaction, contribute only to the production of living creatures; but also produces the rudiments of vegetables: as appears in moss; and the roughness on the coats of some trees.

Having once, by accident, left a cut citron in a parlour, for two months in the summer; I afterwards found a sprouted putrefaction on the part that was cut, appearing to rise in certain hairs, the height of an inch; and on the top of each hair grew a head, like the head of a small

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* This instance should be well considered, as to its justness; or rather a competent set of experiments should be made to determine the fact: for it appears not exactly determined at present.

iron nail; thus plainly beginning to resemble a plant*.

In like manner rust is produced on metals; scurf on glass, &c. from the dilatation of the native spirit, which swells, and drives the grosser parts before it; so as to thrust them out at the surface.†

It should be examined whether the earth swells on its surface, especially where the glebe lies spongy and hollow. There have sometimes been found trees, like the masts of ships, lying buried under ground, to the depth of several feet: whence it should seem, that such trees were once blown down by storms; and that the earth gradually raised itself over them.‡

The earth swells, manifestly, and suddenly, in earthquakes; at which time there frequently

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* This experiment seems not contingent but constant. And the curious microscopical observers have made several species of these kinds of superfœtations, or vegetations upon vegetables. See Mr. Boyle, Dr. Hook, Dr. Grew, the French Memoirs, &c.

† If the cause of rust were here justly assigned; ought not the same effect to happen in vacuo? The fact may deserve to be better enquired into; the several ways of making crocus martis considered; the composition and faults of glass examined, &c.

‡ See the account of the generation of mosses, in the Philosophical Transactions. See also Mr. Evelyn's Sylvia.

burst forth springs of water; wreaths, and globes of flame; violent and strange winds; and stones and ashes are tossed into the air.

But all earthquakes are not sudden; for sometimes the earth continues in a tremor several days: and in our time there was, in Herefordshire, a very small, gentle, and slow earthquake; wherein some acres of land continued gradually moving for a day together; and then transferred themselves into another place, that lay not far off, upon a declivity: and there rested.†

It should be examined, whether the body of the waters does sometimes swell in the seas; for the flux of the sea must either happen, 1. from a progressive motion; 2. the rising of the waters upwards, by some attractive virtue; or else, 3. from some tumefaction or relaxation in the waters themselves. And this latter, if it be any cause of the flowing of the sea, belongs to the present enquiry†.

The water swells and falls again in certain springs and wells; as if it were in the way of ebbing and flowing.

There also sometimes break out, in certain places, springs of water, without any preceding

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* This kind of local motion, likewise said to happen in certain sandy desarts, requires to be further examined.

† See the Novum Organum, part ii. aph. 36.

earthquake; and this in certain periods of years, from uncertain causes. Such eruptions of water generally happen in great droughts.

It should likewise be observed, that the seas sometimes swell out of the time of flood; and without any external wind: and that this generally precedes some great tempest or storm.

PRECEPT.

It is worth trying, whether some relaxation may not happen in the body of water, even in a small quantity. But to expose water to the sun or air, would rather consume it; therefore the experiment should be made in a close glass. For example, into a large bellied glass, having a long and slender neck, pour so much water as may fill the belly, and lower part of the stem. Let this be done in a dry season, when the wind stands northerly; and let the glass remain thus till the weather becomes rainy, and the wind southerly; then observe whether the water rises at all in the neck of the glass*. A careful enquiry should also be made about the swelling of water in wells; as, whether it happens more by night than day; and at what season of the year.

* See Novum Organum, part ii. aph. 13.

HISTORY.

1. In rainy weather, the pegs of violins become swelled, and hard to screw; so likewise wooden drawers are harder to draw out, and doors with wooden hinges, harder to open in wet weather.

2. The strings of a violin are apt to break, when tight stretched in rainy weather.

3. The humours in the bodies of animals, are observed to be relaxed, to swell, to run, to oppress, and block up the pores most, in rainy weather, and southerly winds.

4. It is a received opinion, that the humours and juices, not only in animals, but also in plants, swell and fill up the cavities most about the full of the moon.

5. Salts dissolve, open, and dilate themselves in moist places; so likewise, in some measure, do sugar and sweat-meats: which are apt to grow mouldy, unless they stand in a room where fire is sometimes kept.

6. All things that have passed the fire, and are considerably shrunk, grow somewhat relaxed with time.

7. Diligent enquiry should be made into the tumefactions and relaxations of the air; and how far the causes of the wind depend upon them: since vapours are neither commodiously

collected into rain, nor dissipated into clear air, without causing swells in the body of the air.*

SECT. IV.

OF THE DILATATION AND RELAXATION OF BODIES BY MEANS OF FIRE, AND ACTUAL SIMPLE, EXTERNAL HEAT.

TRANSITION.

FROM the heap of nature, we have above taken a few instances of the dilatation of bodies owing to their native spirit; whether in maturations, the first rudiments of generations, the excitations by motions, natural and preternatural irritations, or in putrefactions and relaxations: we next come to those openings and dilatations procured by fire, and actual external heat.

ADMONITION.

The relaxations of bodies by heat or fire, properly belong to the titles of heat and cold, the motion of dilatation, and those of separations, and alterations: but they must be touched under the present title; because, without a little knowledge of them, the enquiry of density and rarity cannot be well conducted.

* See the History of Winds, passim.

HISTORY.

1. Air is simply dilated by heat: for in this case there is nothing separated or emitted, as in tangible bodies; but barely an expansion made.

2. In the case of cupping-glasses, when the glass and the air it contains, are heated, the glass is applied to the skin; and soon after, the air which was dilated by the heat, gradually contracts itself, as the heat decreases; upon which the flesh is thrust into the glass by the motion of connexion*. If it be desired that the cupping-glass should draw stronger; let a sponge be dipt in cold water, and applied to the belly of the glass: for by this coolness, the internal air, will be more attracted, and the attraction of the glass increased†.

3. If a glass be heated, and inverted into water, it will attract the water; so as to fill a third part of the cavity: whence it is plain, that the air was rarified by the heat, in that proportion. But if, instead of a thin glass, which will not bear a great heat without danger of breaking;

* See this motion explained in the Novum Organum, part ii. sect. ii. aph. 48.

† This explanation in some measure holds, notwithstanding the present manner of accounting for effects of this kind, from the direct pressure of the air without; and its rarification within.

an iron or copper vessel were employed, and heated to a greater degree, we judge that air might be dilated above twice or thrice more; which is an experiment very well worth trying: as likewise, to ascertain the degree whereto the air may be rarified; that we may the better judge of its degree of rarifaction in the upper regions; and thence of the ether itself†.

4. It appears very plain, from the thermometer, that a small increase of heat may prodigiously expand the air; so that the hand laid upon the glass, a few rays of the sun, or even the breath of the by-standers shall affect it: nay, the tendencies of the external air to cold and heat, though imperceptible to the touch, do yet constantly dilate and contract the air in the glass*.

5. Hero describes an altar built so artificially, that when the offering is lit up thereon, water shall of a sudden descend, and put out the fire. No other contrivance is requisite to this purpose, than to leave a close hollow space under the altar, filled with air, which being heated by the fire, and consequently dilated, shall find no

* See Mr. Boyle's pneumatical experiments to this purpose.

† See this weather-glass described, Novum Organum, part ii. aph. 13.

exit but through a pipe rising along the wall of the altar; and having its mouth bent down at last, so as to discharge upon the altar. This upright pipe was filled with water; and had a belly in the middle, that it might contain the larger quantity; and a stop-cock at the bottom, to prevent the water from falling through; which stop-cock being turned, admitted the dilated air to rise up, and drive out the water.*

6. It was the invention of Fracastorius, to recover persons from apoplectic fits, by applying a heated metalline pan, at some distance, round the patient's head; in order to dilate, excite, and revive the spirits stagnating, congealed, or blocked up by the humours, in the cells of the brain.

7. Butterflies, and the like creatures, which lie for dead in the winter, recover motion and life by being warmed before the fire; or by the rays of the sun. And persons in fainting fits, are brought to themselves by taking, internally, such liquors as are spirituous and heating, as well as by external heat, friction, and motion.

8. Water opens or expands itself, in the following manner. With the first heat it emits a small and rarified vapour; without any other

* Here add the modern contrivance of making Jet d'Eaux, and fountains by the spring of compressed air.

visible change in its body. Upon continuance of the heat, it does not rise in its whole body, nor in small bubbles, in the way of froth; but ascends in larger and rarer bubbles, and resolves itself into a copious vapour; which, if not obstructed, checked, or condensed, mixes with the air; being first visible, but afterwards diffusing itself, and becoming insensible.

9. Oil opens itself thus. With the first heat, certain little drops ascend; or small grains diffuse themselves through the body of the oil; and this with a small crackling noise: in the mean time, no bubbles play upon the surface, as in water; nor does the whole body swell, or emit any considerable exhalation. But, after some continuance, the whole body rises and dilates itself, very considerably; expanding, as it were to double the bulk: and going off in a very copious and thick exhalation. This exhalation, if it does not take flame, at length mixes with the air; as does the vapour of water. But oil requires a greater degree of heat to make it boil; and begins to boil much slower than water.*

10. Spirit of wine rarifies, or opens itself, rather like water than oil: for it boils up in large

* Lead melts at the bottom of oil, before the oil begins to boil.

bubbles, without froth, or elevation of the whole body; but it expands and flies off with a much less degree of heat, and with much greater velocity, than water. It partakes both of an aqueous and oily nature: readily mixes with air; and suddenly takes flame.

11. Vinegar, verjuice, and wine, open themselves differently in this respect, that vinegar rises in smaller bubbles, and more about the sides of the vessel; but verjuice and wine in larger bubbles, and more in the middle of the vessel.

12. In general, unctuous liquors, as oil, milk, fat, &c. rise and swell in their whole body, at once; whilst ripe juices, (and unripe ones still more) rise in larger bubbles; but old and vapid juices, in smaller.

13. It is common for all liquors, even oil itself, before they boil, to throw, now and then, a few kind of half-bubbles about the sides of the vessel.

14. It is likewise common for all liquors to open themselves sooner, and to boil, and consume, in a small quantity, than in a large one.

ADMONITION.

The experiments about the opening of liquors should be made in glass-vessels; that the motion in the body of the liquor may appear more

visible; and upon little furnaces with equal degrees of heat, that their differences may be the more exactly noted. The fire also must be gentle; because when vehement, it hurries on and confounds the actions of bodies*.

HISTORY.

1. There are numerous bodies, not of a liquid, but solid consistence, that by heat acquire a degree of fluidity, so long as the heat continues to agitate and expand them; such as wax, suet, butter, pitch, rosin, gums, honey, lead, gold, silver, brass, copper, &c. though they require not only very different degrees of heat to open them; but also different modifications of the fire and flame. For some metals melt over a common fire; as lead: others require a fire animated by bellows; as gold and silver; and others again, the admixture of certain matters. So steel does not melt without the addition of some sulphureous body.

2. But if the fire be continued brisk and strong, all these substances not only open by colliquation; but also undergo a second opening, as that of volatility and waste, except gold alone. Quicksilver, which is a natural fluid, begins with this second kind of opening; and is easily vola-

* A complete table of this kind is still wanting: and should be derived from express chemical experiments.

tilized. But with regard to gold, it still remains a question, whether it can be rendered volatile, pneumatical, or potable, as they call it; that is, not soluble, as by means of aqua-regia, which is a common and obvious operation; but digestable, or alterable by the human stomach. And the genuine criterion of this change is not, that the gold becomes volatile in the fire; but so subtile and attenuated as to be irreducible to metal again.*

3. Let farther enquiry be made about glass and vitrified bodies, whether they are consumable by fire, and convertible into pneumatical bodies: for glass is accounted a fixed and juiceless body; and vitrification the destruction of metals.†

4. All bodies capable of fusion, begin the process of it from the lowest degree of opening; viz. softness, and suppleness, before they melt and run; such as wax, gums, metals, glass, &c.

5. But iron‡ and steel, when perfectly purified and unmixed, bear a simple fire, without proceeding farther than to a degree of softness; so

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* This point seems not hitherto settled to general satisfaction.

† But improperly, as metals are easily recoverable from their glasses.

‡ Viz. hammered iron.

as to become malleable and flexible, but not fusible, thereby.

6. Iron and glass, when opened to the abovementioned degree of softness, seem to be dilated in their included spirit; whence their tangible parts are so wrought, as to lay aside their hardness, and resistance; though the whole body is not, at the same time, visibly dilated, or swelled. But upon an exact enquiry: there will be found a certain invisible tumefaction, and agitation of parts therein; though this be restrained by their close and compact nature. For if thoroughly ignited glass be laid upon a stone table, or other the like body, though well heated before hand; the glass will break, through the hardness of the stone resisting its secret tumefaction: and therefore, in taking glass out of the melting-pot, in order to blow it, they usually roll it upon some certain powder, or soft sand; which may gently give way, and not oppose this tumefaction in the parts of the glass.

7. Bullets likewise shot from a gun, after their projectile motion entirely ceases, so as that, to the eye, they shall seem perfectly at rest; yet a great shuddering motion, or pulsation, will be found, in their small parts, for a long while after: insomuch, that if any proper matter be laid upon them, it will thence receive and manifest a considerable force; and this proceeds not so much

from the burning heat, as from the tremor of percussion.

8. Rods of wood being fresh gathered, and kept turning in hot embers, acquire a softness; whence they may be bent at pleasure. And this experiment should be tried in old rods and canes.*

9. Combustible bodies open so, as by fire, first to emit a fume; then to take flame; and, lastly, fall into ashes,

10. Bodies which contain an aqueous moisture, that refuses the flame, and yet are close and compact; as bay-leaves, salts, &c. open by the fire in such a manner, that the aqueous and crude spirit they contain, being dilated by the heat, bursts out with a crackling noise, before they take flame: but if a body at once emits a flatulency, and takes flame, a violent tumult, and a powerful dilatation ensues; that flatulency, like bellows on the inside of the body, blowing and expanding the flame every way, as in gunpowder.

11. Bread swells or rises somewhat in the oven; though it loses a little of its weight. And on the top of the loaf sometimes gathers a kind of crusty bubble, or bladder; so that there

* It has even been tried in large timbers for ship-building, with considerable success.

remains a cavity filled with air, between the pelicule of the crust, and the second surface of the loaf.

12. Roasted flesh also acquires a degree of tumefaction; especially when the outward skin is left upon it: as we see in roasted pigs, &c.

13. But roasted fruits sometimes leap out of the fire; as chesnuts: sometimes burst their skin, and spirt out their pulp; as apples: and if scorched by the fire, they acquire a burnt or scaly crust; and, as in the above-mentioned case of bread, leave a cavity between that crust and the flesh of the fruit. The same thing likewise happens in eggs.

14. But if the heat be slow, and without manifest fire, and there be also no ready vent for the vapour; as when pears are roasted in the warm ashes; and still more remarkably when the bodies to be treated are put into pots, and then buried under the ashes, or set in the oven, &c. in these cases the tumefaction or dilatation is repelled, by the heat, and turned back upon itself; whence ensues a condensation, as in distillation; and the body is more moistened, and, in a manner drowned with its own juice: as appears in pies, tarts, and other works of pastry and the oven.

15. But dry bodies, if the flame be suffocated and find no easy exit, become rarified, hollow,

and porous: as we see in charcoal, and the pumice-stones discharged from burning mountains.

SECT. V.

OF DILATATIONS BY EXTERNAL HEAT, AND DISTILLATIONS.

THERE are two kinds of dilatation, opening, or attenuation, of bodies in distillations; the one in passage, when the body is turned into vapour or fume, which is afterwards restored; the other in the body so restored; which is always more rarified, more subtile and expanded than the crude body from whence it was distilled: as rose-water, for example, is more rarified and light, than the juice of roses.

All distillation is performed by a kind of flux and reflux, or alternate rarifaction and condensation; the one raising the vapour, or rendering the body pneumatical; and the other striking it back, or restoring it to a tangible state.

The actions of dilatation and condensation, are not pure in the case of distillations; but the separation of heterogeneous parts intervenes: which is the intentional action with regard to practice; whereby the purer juices, the phlegm, the oil, the fine parts, and the gross parts of bodies are separated from each other.

Under distillations it is proper to enquire into, and determine, the degrees and diversities of heats; as that of coals, a hot oven, that of baths, that of water, ashes, sand, &c. that of the sun, horse-dung, fire left to itself, fire animated by bellows, fire confined and reverberated, heat ascending, heat descending, and the like; all which have a remarkable efficacy in the opening of bodies; and particularly in the complicate actions of dilatation and contraction. For these heats seem by no means to resemble the heat of the sun, and celestial bodies; neither in gentleness, softness, temperature, continuance, retraction, modification by intermediate bodies; nor in ebbing and flowing, with the remarkable inequality of day and night. But all these particulars should be diligently examined, under the general titles of heat and cold; with their subordinate divisions.*

Distillations, and the dilatations they cause, are performed in a close vessel; where the body to be distilled, the vapours it affords, and the air, are shut up together: for in the common stills and alembics, the external air is not excluded from entering, in some degree, the pipe of the still-head, or nose of the worm. But in retorts,

* See Mr. Boyle's History of Cold; and the Chapter of Fire in Dr. Boerhaave's Chemistry.

where a stronger heat is required, the external air has no entrance; the mouth of the receiver being joined by a luting to the neck of the retort; so that the whole process of rarifaction and condensation is performed within. But if the body be full of a vigorous spirit, as nitre or vitriol, it requires a capacious receiver; that the vapours may freely play about therein, without bursting the glass.

PRECEPTS.

1. But though distillations are performed, as it were in a close cell; yet there is still space enough allowed for some parts of the body to expand into vapour, and other parts to subside in fæces; and again, for the vapours to wind and roll about, restore themselves, and, when of different natures, to separate one from another. The following precept, therefore, is of the utmost importance; as it may advance a method of putting nature to the scrutiny, and producing new transformations: for the fire of the chemists and physicians, though it has produced many useful things; yet does not, perhaps, obtain the more genuine virtues, and properties of heat, by reason of the distractions and separations of the parts, which constantly happen in their operations. The sum of our precept, comes to this, that all separation, and all flux and reflux of rarification and condensation, be totally prohibit-

ed; and that the heat be spent entirely within the body itself, and its cavities. Such a method may possibly hold the Proteus matter, bound and manacled; and compel it to try all its shapes and conversions, in order to free and clear itself. Numerous instances occur to us, with regard to this affair; and others may be discovered: but we will here propose only an easy example or two, the more fully to express our meaning.

2. Having provided a cubical vessel of iron, the sides whereof are very strong and thick; fit a cube of wood exactly to it, so as perfectly to fill the cavity: then, in the securest manner, fix and lute on a strong cover of the same metal, so as not to give the least vent; but remain capable of bearing the heat. Now place the vessel in the fire, and there continue it for some hours; afterwards take off the cover, and examine what change the wood has suffered. It should seem, that as the wood in this case, could neither flame nor emit a fume, so as to discharge any of its pneumatical or moist parts; the body of the wood must either be converted into a kind of amalgam; or resolved into air; that is, a truly pneumatical body; leaving at the bottom, certain feculent parts, grosser than ashes; and some incrustation on the sides of the vessel.*

* The experiment seems to have never been tried.

3. Let trial also be made of a quantity of pure water, that shall perfectly fill a like kind of iron-vessel: but here the fire should be more gentle; and the operation of longer continuance. The vessel also might be removed from the fire at certain hours; and afterwards put on again: and this for several times. We make choice of pure water for this experiment, because water is a simple body, without colour, smell, taste, or other remarkable qualities. And, therefore, if by a mild and gentle heat, an interchange of heating and cooling, and a prevention of all evaporation, the spirit of the water shall not be lost, but still be wrought upon, and become attenuated by this kind of heat, so as to turn itself upon the grosser parts of the water, and digest and change them into a new texture and arrangement, of greater simplicity and uniformity; the water thus acquiring either a different colour, smell, taste, a degree of oiliness, or any other considerable alteration, like what we find in compound bodies; doubtless it would prove a great acquisition, and open a way to numerous particulars of moment.*

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account, perhaps, of the danger that may be apprehended from the bursting of the vessel. But any inconveniences of this kind might be prevented by an artist.

* Because it would then afford a practical instance of the transmutability of bodies. See the Sylva Sylvarum.

4. In this method of close distillation; that is, where no space is allowed for evaporation; any one may easily invent many other experiments. And this we are certain of, that a suitable heat operating upon a body, without separating or consuming its parts, may produce wonderful effects and changes of structure*.

5. We might add, as an appendix to this precept, that some method should be discovered (which certainly is not difficult) whereby heat may operate, not only in a close, but in a tensile, or extensible vessel: which is the case in a very natural matrix, whether of vegetables or animals. For such an operation extends to many things, not performable by simple confinement. This contrivance does not regard the pygmy of Paracelsus, or any such monstrous trifles; but things of weight and solidity. For example, close distillation can never make a total conversion of water into oil; because oil possesses more space than water: but if the operation were performed in an extendible body: perhaps this transformation might be effected:

* It should seem that great light might be derived to philosophy from this kind of digestor, as there has been from the air pump, telescope, &c. See Dr. Papin's account of his digestor; and let the contrivance be improved, transferred, and varied; and a proper set of leading experiments be tried upon this, and other kinds of digestors

which would be a thing of prodigious use; as all alimentation principally depends upon fat*.

6. It were a proper and very useful thing, sometimes in distillations to compel nature to an account; and take a just estimate of the quantity lost in the operation: that is, of the quantity grown pneumatical; and again of the remaining part, whether fixed or restored in the body. This may be done by first weighing the body to be distilled, and the vessels wherein the operation is to be performed; and after the operation is over, weighing the distilled liquor, the fæces, and lastly the vessels again: by which means may be learned what proportion was restored; what proportion remained in the fæces; and what adhered to the vessels; and the deficiency of the three several weights, compared with the weight of the whole body, will shew what proportion was rendered pneumatical.†

* See the Sylva Sylvarum, passim.

† Something of this kind has been done by M. Lemery in his course of chemistry; but Mr. Hales in his Vegetable Staticks, has prosecuted the thing with great exactness; and more directly to the present purpose.

SECT. VI.

OF THE DILATATIONS AND RELAXATIONS OF BODIES BY THE REMISSION OF COLD.

TRANSITION.

We proceed from the dilatations and rarifactions caused by actual heat, to the dilatations and relaxations produced by the remission of violent and intense cold: and this remission should be esteemed a comparative degree of heat.

1. Bodies froze by violent cold; but not so far as, by the continuance of the cold, to remain fixed in their condensation; open and restore themselves without manifest heat; and barely upon a remission of cold: as in ice, hail, snow, &c. but they do this much quicker upon the application of manifest heat.

2. But the more delicate substances, whose vigour consists in a subtile native spirit; as apples, pears, pomegranates, and the like; have their spirit suffocated by congelation; so as not again to recover their pristine vigour upon thawing.*

* Unless thawed by being put into cold water.

3. Wine likewise, and malt liquors, grow flat to the taste, and lose of their vigour upon freezing: yet they revive, relax, and as it were ferment again after thawing, when the weather becomes warm, and the wind southerly*.

SECT. VII.

OF THE DILATATION AND RELAXATION OF BODIES BY POTENTIAL HEAT; OR THE AUXILIARY SPIRITS OF OTHER BODIES.

TRANSITION.

As to the subject of potential heats, it is proper to consult the medicinal tables of secondary qualities; which exhibit the things that operate by dilatation, upon the human body: and they are in general such as these, viz.

1. Cardiacs, which dilate the spirits oppressed.

2. Abstergents, which strengthen the expulsive faculties.

3. Aperients, with regard to the orifices of the veins and vessels.

4. Aperients, with regard to the pores and passages of the parts.

* The particulars wanting in this section, may in great measure be derived from Mr. Boyle's Experimental History of Cold.

5. Digestives, which ripen at the same time.

6. Digestives, which discuss at the same time; and,

7. Caustics, which burn and consume the flesh.

These things have their effect principally by dilating the spirits, humours, juices and the substance of the body, by means of auxiliary spirits; and again by a stimulating virtue which such medicines have in contact with the parts of the body, whether used internally or externally.

SPECULATION.

It appears from the weather-glass what an exquisite sense, or perception, the common air has of heat and cold; as immediately shewing the most subtile differences and degrees thereof. And we judge, that the perception of the spirits in animals, as to cold and heat, is much more acute and subtile: only the air is a pure and genuine pneumatic body, that has no tangible parts mixed among it; and the perception of the spirits is dulled and blunted by the tangible body in which they are detained. But notwithstanding this impediment, the spirits of living creatures, seem more delicate or sensible, than the air itself: for it has not hitherto appeared, that potential heat can cause a dilatation of the

air; whereas it certainly has that effect upon the spirits contained in the parts of animals: which is manifest from the secondary qualities of medicines. But of this let farther enquiry be made; according to the following precept.

PRECEPT.

Take two weather-glasses, of the same size; fill the one with water, and the other with rectified spirit of wine; heat the glasses in such a manner, that both the water and the spirit may stand at the same height; then place them together, leave them a time, and observe if the water stand higher than the spirit: for if it does, it is plain that the potential heat of the spirit of wine expands the air, so as to depress the spirit*.

It might be very useful, sometimes to try and exercise the operations of the secondary medicinal qualities in lifeless bodies. For although no effect could be expected from most of them; as a living spirit is absolutely required to actuate them, on account of the subtilty of the operation; yet others of them would have an opera-

* The difference may proceed from the spirit of wine being more rarifiable by the warmth of the external air, than water; but whether rarifaction be the form of heat is not hitherto satisfactorily determined. See the Novum Organum; part ii. aph. 12, &c.

tion upon some inanimate bodies. Thus, we see what effect salt has upon flesh, spices upon dead carcasses, rennet upon milk, leaven upon bread, &c. The diligence therefore of physicians, as to their secondary qualities, may, if judiciously considered and transferred, serve in performing numerous other operations: always supposing that a stronger virtue is required to operate upon a dead body than a live one.*

SECT. VIII.

THE HISTORY OF DILATATION IN BODIES BY A RELEASEMENT OF THEIR SPIRIT.

TRANSITION.

We come next to the dilatations of bodies made by a releasement of their spirits, upon breaking the prison of the grosser parts, which closely detained them, so that they could not dilate: for in bodies which have a compact closeness and remain strongly bound together in their wholes, the spirits cannot perform their office of dilating; unless there be first a solution of continuity in the grosser parts, made either by cor-

* The proper use seems not hitherto made of this precept.

rosive liquors, with or without the assistance of heat: and this appears in the opening and dissolving of metals.

1. A penny-weight of pure gold may be reduced by the hammer, into thin plates: so as to be readily torn betwixt the fingers.

2. If the gold be now put into a glass, with four times its quantity of aqua regia, and the glass be set over a very soft and gentle fire; there will soon appear to arise therein certain little grains, which, after a small continuance, diffuse themselves and incorporate with the liquor; so as to render it bright and shining; as if tinged with saffron. But the gold, in the proportions here set down, dissolves only to a third; for the menstruum will imbibe no more: so that if the whole penny-weight of gold were to be dissolved, the saturated menstruum must be poured off; and again four penny-weight of aqua regia poured on; and so for the third time. This dissolution proceeds calmly, and slowly, in a moderate heat, without fumes, and without heating the glass, more than what the fire occasions.

3. To a quantity of crude quicksilver, put into a glass, add twice its weight of aqua fortis; and without setting the vessel to the fire, there will presently rise up something like a very fine powder, in the body of the liquor; and in the

space of an hour, without fire, without fumes, and without tumult, the mixture will appear a clear uniform liquor.

4. Put a penny-weight of thin plated lead to nine penny-weight of aqua fortis: the lead will not here incorporate so well as the other metals; but the menstruum throws down the greater part of the lead, in form of a calx, to the bottom; the liquor above, remaining somewhat turbid, though tending to transparency.

5. To a penny-weight of plated silver, add four penny-weight of aqua-fortis; set them in a gentle heat: and the silver will rise within the body of the liquor, like small sand, or bubbles, a little larger than those of gold; and incorporate with the menstruum, and turn with it into a thin, white, and as it were, milky liquor: but after standing and cooling for a while, icy plates appear to shoot in the body of it, proceeding from the mixture of the metal and the menstruum: but when, after a longer stay, the separation is totally made, the liquor becomes clear and crystalline; throwing the icy plates to the bottom. The menstruum here sustains the full weight of the metal; as in gold; and the dissolution is made almost with the like heat; and does not increase it by motion, any more than in the case of gold.

6. Six penny-weight of aqua-fortis being put to one penny-weight of copper-filings, and set in a sand-heat; the copper rises in larger grains, or bubbles, than silver; and soon after incorporates with the menstruum into a blue turbid liquor; but upon standing, it brightens up, like the sky, into a shining beautiful blue; throwing down the fæces, in form of powder, to the bottom; which fæces, however, are diminished in time, and ascend and incorporate with the rest: and thus six penny-weight of aqua-fortis dissolves one penny-weight of copper, entirely; so that the menstruum here suffers itself to be charged with twice the weight it did in the case of gold and silver. But the solution of copper conceives a manifest heat, by the internal conflict, even before it is applied to the fire.

7. Three penny-weight of aqua fortis being added to one penny-weight of tin-filings, the whole metal is turned into a body like cream or curds, which does not readily clarify itself; but conceives a manifest heat without fire.

8. Nine penny-weight of aqua-fortis being poured upon one of iron-filings, the metal, without heat, rises up in large bubbles; not only within the body of the liquor, but above it; so as to boil out at the mouth of the glass: at the same time emitting a copious, dense and saffron-

coloured fume; with a violent conflict, and a great degree of heat, insufferable to the hand.

ADMONITION.

No doubt but the different properties of different menstruums, and the manner of applying the fire or heat, may cause some alterations in the form wherein metals open themselves.

PRECEPT.

1. Observation should be made, what kind of dilatation happens in the opening of metals; as whether it be like that of leaf-gold, which is a spurious rarifaction, wherein the body is dilated rather in place than substance, after the manner of powders; or whether the body of the metal be actually dilated in substance. This may be determined by the following experiment. Take an exact weight and measure of quicksilver, and so of aqua-fortis, after the manner of our first table; then make a solution thereof, and weigh it in the two vessels, wherein the quicksilver and aqua fortis were separately weighed; and observe whether the weight and measure of the compound exactly answer to the weight and measure of the same bodies, when separate. We make choice of quicksilver* for this experiment,

* Some attempt of this kind was made by Dr. Hook, and Dr. Grew, but the matter perhaps has not been duly prosecuted.

because, as it dissolves without fire, there is the less suspicion of waste.

2. It should be observed, whether a solution of quicksilver may not support the heaviest stones, or even tin, so as to keep them floating. This might be collected from knowing the proportions of their specific gravities. And let not this be suspected as tending to miracle and imposture; but only to the investigation of the nature of mixture*.

OBSERVATION.

It is worth observing, that all metals, though remarkably heavier than the menstruums in which they dissolve, yet ascend in the form of sand or bubbles, during the first act of solution: and this is the more considerable where they do the same without fire, as in the case of quicksilver.

SPECULATION.

The tumult happening among the parts of the bodies in the dissolution, is the cause that the metals ascend in this manner: for bodies are somewhat impelled by a local motion in all violent corrosion; as plainly appears from little gravelly stones, which being put into strong vi-

* See Dr. Grew's discourse concerning the nature, causes, and power of mixture.

negar, on the sides of a porringer, that they may easily slide; continue moving, or, as it were, swimming by fits, like little fish. There is also a a kind of fossil, which, when put into vinegar, moves and runs up and down therein, with a restless motion. But the bodies that mix without this tumult, do not perhaps readily ascend, without shaking: so sugar dissolving at the bottom of water does not dulcify at the top; nor saffron, in like manner, tinge, without commotion and agitation*.

SECT. IX.

THE HISTORY OF DILATATION, UPON THE MEETING AND UNITING OF BODIES RELATED.

TRANSITION.

We must next come to another kind of dilatation, commonly called by the name of dissolution, in some cases. This happens where bodies run into the embraces of one another, and, if possible, open themselves, so as to receive each other internally. But this relaxation does not happen with any tumult, or by the penetration of the entering body, as menstruums penetrate

* See Mr. Boyle upon Fluidity and Firmness.

metals; but calmly, and by a relaxation of the receiving body.

1. Sugar and some gums, viz. gum tragacanth, gum arabic, &c. being put into water, resolve; as willingly relaxing their parts, like a sponge, to receive the liquor in amo gst them.

2. Paper, fur, wool, and the like porous bodies being plunged in aqueous liquors, or otherwise moistened, open themselves, so as to become more soft, yielding, separable, and as it were, putrified.

3. Sudden joy remarkably dilates the spirits of men; as upon the hearing of good news, seeing the object desired, &c. and though there be here no contact of bodies; but only an act of the imagination; yet this act is sometimes so powerful, as to endanger sudden fainting, or even death itself. And something of the like kind happens when the imagination is earnest upon venereal pleasures.

PRECEPT.

All endeavours should be used to discover peculiar menstruums for each particular substance; since, in all probability, there are liquors, and soft pappy bodies, that have such a sympathy, or correspondence, with particular matters, that upon the application thereof they will readily relax their parts, willingly imbibe the others, and thus become mollified and renewed in

their own juices. And this regards one of the capital things in all nature; viz. the refreshing, and recruiting the most radical and essential moisture of bodies from without; such as flesh, bone, membranes,† wood, &c. So likewise there is a sympathy, or correspondence, in the bodies which operate by divulsion, and penetration; for aqua fortis does not dissolve gold, nor the common aqua regia silver†.

SECT. X.

THE HISTORY OF DILATATION BY ASSIMILATION, OR THE CONVERSION OF A GROSSER MATTER TO SUCH AS IS MORE SUBTILE.

TRANSITION.

We next pass to the dilatation by assimilation or conversion; wherein the more over-ruling, and more active body subdues the other that is more obsequious and passive; so as actually to turn that into itself, and multiply and renew its own substance thereon: but if the body thus assimilating be more subtile and rarified

* See the History of Life and Death, passim.

† Upon finding out these sympathies, or relations, betwixt bodies, and the menstruums they indicate, the perfection of chemistry, and a large part of natural philosophy, seems to depend.

than the body assimilated, this assimilation of necessity produces dilatation.

1. Air licks up the humidity of the earth, preys upon it, and converts it into itself; but chiefly when in commotion, as in the case of winds*.

2. The process of desiccation in woods, plants, &c. that are not very hard, or stubborn, turns upon the depredation of the air; which draws out, sucks up, and turns to its own substance, the spirit of the body: whence this process proceeds but slowly in fat, and oily bodies; because their spirit, and moisture, are not so nearly of the same substance with the air.

3. The spirits of tangible bodies feed and prey upon the grosser parts of the body, that includes them: for the spirits which approach nearest to air, obey its call, and go forth suddenly; but those which reside deeper in the body, prey upon the more internal parts that lie contiguous, beget new spirits thereon, join these to themselves, and at length fly off together: whence such bodies by age, or long lying, diminish in their weight; which could not possibly happen, unless some tangible part were gradually converted into an untangible or pneumatical one; for spirit once formed in a body, has no

* See the History of Winds, passim.

longer any gravity in that body, but rather helps to lighten it*.

4. Many tumours in the bodies of animals are discussed by insensible perspiration, without suppuration; and rendered perfectly pneumatical, subtile, and perspirable.

5. Flatulent eatables produce windiness in the body; their juices being converted into flatus, and air; which escape by eructation and otherwise: though sometimes not without extending, and griping, the internal parts. The like also sometimes happens from the most approved aliment, by reason of a weakness in the digestive faculties.

6. In every body requiring aliment, when the parts nourished are finer or more subtile than the nourishment; alimentation must necessarily cause a dilatation. Thus the spirits and juices of animals are lighter than the solids, or liquids, that nourish and supply them.

7. Of all openings, dilatations and expansions, the greatest in proportion to the body before and after the dilatation, the quickest, and of least

* If this be meant of specific gravity; or supposing the body weighed in air; it may be readily allowed: but if meant of absolute gravity; or supposing the body weighed in a vacuum: it will perhaps require more exact experiments to determine it.

duration, is that of oily and inflammable bodies into flame; which seems to be done copiously, and at once, without stop or degree. And here the succession of the flame is plainly a kind of assimilation; whilst the flame multiplies itself upon its fewel.

8. But the most powerful thing of this kind, not with regard to the suddenness of first catching flame (for brimstone, camphire, or petreol catch flame sooner than gunpowder) but with regard to the succession of the flame once caught; and overcoming all resistance; is that mixed expansion beforementioned, of gunpowder into flame and air; as in the firing of cannon; the blowing up of mines, &c.

9. The chemists observe a very violent expansion of quicksilver by the fire, and also of a preparation of gold; so as to explode in a dangerous manner; and give a report like that of a gun*.

* Viz. the Aurum Fulminans.

SECT. XI.

OF DILATATIONS OR DISTRACTIONS BY EXTERNAL FORCE.

TRANSITION.

We should next proceed to those dilatations, distractions, or divulsions, that proceed not from any appetite in the body dilated; but from the violence of external bodies, which, prevailing with their motions, lay the body under a necessity of being dilated, or stretched. This enquiry, however, belongs to the title of free motion; but, as in the former cases, so we shall here also add somewhat upon this head. The motion we speak of is generally of two kinds; the one being a motion of distraction from external force; and the other a motion of contraction, or restitution, proceeding from the motion proper to the body. This latter motion though it belong to condensation, is yet so joined with the former, that it may commodiously be treated in this place.

1. Rods of wood, and the like, suffer some degree of forcible bending: which draws the external parts asunder in the bent place; and compresses the internal parts. If the bending force be soon after remitted; the rod flies back and restores itself: but if the rod be long detain-

ed in that curved position, it fixes there, and starts back no more.

2. The case is the same in watch-springs; where the piece of coiled steel has a constant and gradual endeavour to unwrap or restore itself.

3. Cloth, and the like substances, consisting of threads, receive a greater degree of extension; and restore themselves, if soon let go; but not if they have remained long stretched, or tentered.

4. The flesh which rises upon the application of a cupping-glass, is not a tumor; but a violent extension of the entire flesh, by attraction.

5. The following experiment may serve to discover what degree of rarifaction the air is capable of. Take a glass-egg, with a small hole in it; suck out the air as much as possible; then immediately close the orifice with the finger; plunge the egg, thus stopped, under water, and now the finger being removed, the egg will draw in as much water; as there was air sucked out: so as that the remaining air, will recover its former expansion, from which it was forcibly drawn and extended.* And, as I remember, the egg drew in about a tenth part of its own con-

* Mr. Boyle has several apposite experiments to this purpose.

tent of water. I likewise left a glass egg, thus evacuated, and stopped up with wax, a whole day, to try if dilated air might be fixed by time; so as no longer to restore itself, like wood or cloth: but when the wax was removed, the water entered in as before; and even when unstopped in the open air, new air entered at the orifice, with a hissing noise. But the time was here too short for an accurate experiment.*

6. What degree of rarifaction water is capable of, may perhaps be thus discovered. Take a pair of bellows, and draw up as much water with them as may fill their cavity; though without raising the bellows to their height, or but, as it were, half way. Then stop up the bellows; and still continue to raise them by degrees; to see how far the water received will suffer itself to be dilated: or otherwise, draw up water by a pipe, or syringe; then close the orifice; and gradually raise the embolus, or sucker, still higher.†

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* This experiment has been prosecuted by Mr. Boyle, Mr. Hauksbee, and others, by means of this condenser, an engine, which is the converse of the air-pump. But it perhaps, deserves to be carried still farther; by means of a stronger condenser than the common; a greater condensing power than that of a syringe, worked by human strength; a much longer time of rest being also allowed.

† This experiment may perhaps be better tried in the

SPECULATION.

We suspect that the spirit of water* suffers some distraction in congelation; though this seems a very subtile affair. But first, it is certain, that in all baking or burning, as in the baking of bread, the burning of brick, &c. a large proportion of the pneumatical part of the body flies off, and exhales: whence of necessity, the grosser parts contract themselves, in some measure; by the motion of connexion:† for when the spirit is gone off, and no other body easily enters to possess the place deserted by the spirit, the parts come closer together, to prevent a vacuum, as they phrase it; whence proceeds hardness and a contraction of the body. So on the contrary, it should seem that the spirits of bodies are drawn asunder by freezing; for the grosser parts are contracted by cold; so that there is left

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exhausted receiver of the air-pump; by including a spherical glass of water therein; with a long and slender neck: for when the pressure of the atmosphere is taken off, the water will swell and rise visibly in the neck of the glass. Or it might be proper to try how far water expands by a boiling heat; and how far when converted into vapours. For all which let Mr. Boyle, and farther experience be consulted.

* That water has a spirit, see confirmed and illustrated in Dr. Hoffman's New Experiments and Observations upon Mineral Waters.

† See Novum Organum. Part II. Sect. II.

some space unoccupied within the cells of the body: whence it follows, that if no other body succeed, the inherent spirit must be stretched or distracted, by the motion of connexion, as much as the grosser parts are contracted. And this appears to be the case in ice; the body whereof is full of cracks and blebs, and somewhat swelled; whilst the ice itself, notwithstanding the remarkable contraction of its parts, is in its whole, specifically lighter than water: which may, perhaps, be justly attributed to the dilatation of its pneumatical parts.*

SECT. XII.

OF DILATATIONS BY DIFFUSION, OR SPREADING.

TRANSITION.

We come next to the dilatations by diffusion, when a body heaped up and pressed together, is spread out into a plane or flat. But this kind of dilatation is to be accounted spurious; as being made, not in the substance of the body, but in the position of its parts: for the body here remains in the same density of substance, only ac-

* Compare this with the Speculations of Mr. Boyle and Dr. Hoffman upon the same subject. See also below, Sect. XV.

quires a larger figure in surface, and a less in solidity.

1. Gold acquires an immense dilatation by the hammer, as we see in leaf-gold; so again by drawing, as we see in the gilding of silver-wire: for the mass of silver is gilt over, before it is drawn out into wire.*

2. Silver also is, by the hammer, reduced to leaves; though not so exquisitely thin, as gold. The other metals also may be hammered into thin plates.

3. Wax, and the like bodies, may be formed, moulded, and wrought into thin cakes, cases, or coverings.†

4. A drop of ink in the pen is dilated, and spread out into a great number of lines and letters: and the same holds true of the paint of a painter's brush, varnish, &c.

5. A small quantity of saffron tinges a large one of water.‡ And thus much for the dilatations, rarifactions, and relaxations of bodies.

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* For the quantity of this kind of dilatation consult Mr. Boyle's Philosophical Works; and Dr. Halley's Computation, in the Philosophical Transactions.

† As in the callico-wrapper, of the East-Indies,

‡ There are many pertinent instances to this purpose in Mr. Boyle's pieces upon colours, effluvia, phosphori, &c.

SECT. XIII.

OF CONTRACTIONS BY THE EMISSION OR DISCHARGE OF A BODY RECEIVED.

TRANSITION.

We must next, with the like diligence, enquire into the actions contrary to the foregoing; viz. into the contractions, condensations, and closures of bodies. And it seems best to treat this business apart; the rather, because all the actions are not here reciprocal; but some of them peculiar, that require to be explained by themselves. And although they may agree in a contrary respect, yet they are discovered and exhibited by very different experiments.

The action of contraction, by the emission or expulsion of another body, is reciprocal to the action of dilatation, by the introsusception of another body; and therefore this must be first enquired into.

1. Consult the instances of dilatations by introsusception; and compare them with the same instances after the dilatations cease, in bodies where this cessation happens.

2. The pure and perfect metals, though changed and tortured various ways, by sublimation,

precipitation, amalgamation, solution, calcination, &c. are yet generally recoverable by fire and fusion, and convertible into themselves again: the metalline nature having no great agreement with other bodies. But this condensation is the less genuine, as it seems to be nothing more than an emission and exclusion of the air, interposed; or of the menstruums in which the metals were dissolved; thus giving an opportunity for the pure parts of the metallic body to unite again. And, doubtless, the body possesses much less space than before; though it does not seem to become denser in its substance. This power of the keys, which opens and shuts, reigns principally in metals. And thus foul metals, as also marcasites and ores, are purified; the homogeneous parts of them being collected together by the fire; and the dust and dross thrown off and excluded: for every pure metal is more dense and ponderous, than the same when impure.

3. It contributes to condense metals, if they be often melted, and quenched in waters; whereby they become more hard and stubborn: but whether their specific gravity be increased by this means, is not hitherto ascertained; and requires a particular experiment.* This induration, how-

* It has been tried in steel, perhaps, and two or three

ever, is more powerfully effected by frequent solutions and restorations, than by fusions and extinctions: and it should likewise be examined, in what kinds or mixtures of waters, metals acquire the greatest hardness.

4. There are certain ways of killing and destroying metals; so that when dissolved and opened, they shall be no longer capable of reduction. And something of this kind appears remarkably in quicksilver; which, if forcibly ground along with a little turpentine, spittle, &c. the quicksilver is killed, and thence acquires an aversion to recover its pristine form.*

PRECEPT.

Diligent enquiry should be made into the business of mortifying metals, or preventing their reduction, or restitution; for they must have a great antipathy to those things which thus pre-

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other metals; but there ought to be a table formed, including the different gravities of all the metals, after being heated and quenched, a certain number of times, in various liquors: as well waters of different sorts, as the juices of plants, saline solutions, &c. See M. Reaumur's Treatise of converting forged iron into steel; and of softening cast-iron, so as to make works thereof, equally perfect with those of forged iron. Published at Paris, An. 1722.

* For the business of demetallization, see Boyle, Becher, Homberg, and Stahl: but farther experiments, and more decisive, are still wanting on this head.

vent their parts from coming together. And as all restitution of metals is a certain kind of condensation; a knowledge of the privation will here regard the knowledge of the form.

HISTORY.

There is properly, no reciprocal action opposed to the dilatations proceeding from the native spirit expanding itself; contraction being a thing foreign to spirit, which is never contracted, unless it either suffers, is suffocated, or collects itself, in order to dilate more forcibly. We might, however, here commodiously substitute the proper action of the grosser parts; which is an action that may, by accident, be attributed to the native spirit; when, through the escape or emission of the spirit, the parts are hardened and contracted. Now the spirit is discharged, either by its own proper agitation, the solicitation of the external air, or the provocation, or irritation, of fire or heat.

SPECULATION.

Fire or heat, and time or age, have one and the same effect, as to the attenuation and discharge of the spirits, and the actions which follow thereon. But age, of itself, is no more than a period, or measure of motion; and therefore, when we speak of age, we mean a virtue and operation, compounded of the agitation of the native spirit, the surrounding air, and the rays of

the heavenly bodies. But there is this difference, that fire and vehement heat dilate bodies suddenly, visibly, and powerfully; but age, like a very gentle heat, by degrees, slowly, and secretly: for gross fumes and vapours are conspicuous; but not the fine perspirations or effluvia; as is manifest in odours.* But the attenuation and rarifaction of bodies by age, is more subtile and exquisite than that by fire; for fire being sudden in its action, causes the pneumatical parts of bodies to fly off in a hurry; sometimes also, converting the prepared humidity into pneumatical matter, and discharging it: whence the tangible parts strongly wedge one another in; and thus, forcibly, arrest and detain a considerable part of the spirit. But age does not suddenly solicit a discharge of what is rendered pneumatical; which therefore, by remaining longer in the body, gradually and regularly prepares whatever may be digested into a fine substance; whilst but little of the pneumatical matter already formed, gently, and successively steals away: so as, in a manner, to anticipate, and as it were undermine the connexion and closeness of the tangible parts. And, therefore, in dissolutions by age, there is found at the last, but very little tangible substance remaining fixed or clinging together.

* See Mr. Boyle upon Effluvia.

For the rotten powder, left after a long series of years, as the remains of the depradation, such as is sometimes found in old monuments and sepulchres, appears but like the carcass of the matter; and is more effete and exhausted than any ashes made by the fire: for ashes have still a juice that may be drawn from them, and turned into salt; whereas this kind of powder contains no juice, nor salt at all.* But the thing here intended, with regard to the present enquiry, is, that this spirit, so long as it is detained in the body, resolves, mollifies, wears, and preys upon the tangible parts, which, after that is discharged, presently contract and lock themselves close together.

SECT. XIV.

OF CONTRACTIONS BY THE SHRINKING IN OF THE GROSSER PARTS, AFTER THE DISCHARGE OF THE SPIRITS.

HISTORY.

THE skins and membranes of animals grow dry and wrinkled with old age.

Such pears and apples as have been long kept,

* See the whole of this speculation illustrated and confirmed in Boerhaave's Chemistry, particularly under the Processes upon Vegetables.

grow shrivelled; so likewise the kernels of nuts contract and shrink from their shells.

Old cheeses have their coats wrinkled; posts, wood-pillars, pales, &c. contract in their dimensions by long standing, crack, gape and separate; especially when set up green. And the like happens in solid bowls or balls of wood.

The earth cracks and chops in great droughts, and becomes full of chinks on its surface; and these cracks sometimes reach so deep, that water issues out thereat.

ADMONITION.

Let no one triflingly pretend, that this contraction in the case of dryness, is no more than a consumption of humidity; for if that were all, and only the moisture, converted into spirit, flew off; bodies would then retain their former dimensions, and barely become cavernous, like cork or pumice; and not be locally contracted, and lessened in their dimensions*.

HISTORY.

Clay is burnt into brick and tile in the kiln; but if the heat be violent, as in the middle of the furnace, some part of the clay is also changed in its nature, and runs into glass.

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* See Dr. Hook's Micrographia passim; and Dr. Grew's Anatomy of Plants.

If wood be set on fire, and the flame be stifled, the wood turns to a coal: or a substance more light and spongy than wood*.

Most of the metals when covered in a crucible, and set in the fire, especially in a reverberatory furnace, are converted into a friable substance, and calcined.

Many fossil, or metalline, and some vegetable matters, are vitrified by a strong fire.

All bodies capable of tumefaction turn to a coaly substance, and contract their dimensions, if too long exposed to the fire.

Paper, parchment, skins, &c. are not only made to wrinkle in their parts by the fire; but also to curl, or coil, and wind their whole substance into a roll.

Linen cloth being set on flame, aud presently extinguished, turns into a light substance, which scarce takes flame again, but easily ignites; as in the case of tinder.

Fat bodies, as wax, butter, oil, &c. become scorched, foul, and as it were smoky by the fire.

Eggs contract in bulk by the fire, and change the transparency of their whites into an opake whiteness.

If an egg be broke into high rectified spirit of

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† For the full process, see Mr. Evelyn's Sylva; or Boerhaave's Chemistry.

wine, it turns white and hard; as if it were heated over the fire. So likewise bread steeped in the same spirit, appears almost as if it had been toasted.

OBSERVATIONS.

1. So long as the spirit is detained in a body, and excited and dilated by fire, or heat; so long it keeps itself in agitation, endeavours its own escape, softens, supples, and fuses the tangible parts together: and thus to digest, subdue, and work together the parts of bodies, is the proper office of the spirit. But after the spirit has once found an exit, and is discharged, then the work of the parts takes place; and, having been tortured by the spirit, now combine together, and wedge themselves close; as well through an appetite of connexion and mutual contract, as an aversion to motion and disturbance. And upon this follow closeness, hardness, and a stubborness of the body.

2. There is a limit and ultimate end of the process of the contraction in the parts of bodies by fire; for if the quantity of matter be too small to cohere through the violent depredation of the fire, the parts desert each other, are turned to ashes and calcined. And thus much for the contractions occasioned by the discharge of the spirit of bodies; whether it proceed from age, fire, or potential heat.

SECT. XV.

OF THE CONTRACTIONS OF BODIES BY ACTUAL, EXTERNAL COLD.

TRANSITION.

RECIPROCAL to the action of dilatation by actual external heat, is the action of contraction by actual external cold. And this condensation is, of all others, the most genuine and proper; and would likewise be the most powerful, if we had here, upon the surface of the earth, any intense degree of cold. But cold, or a remission of heat, (both which we here consider together) simply condenses some things, without altering their nature; restores others, though imperfectly, that are rarified; and again, perfectly converts and transforms others, by condensation, from one nature to another: each of which we must here touch upon, in their turn.

HISTORY.

1. Air, in a thermometer, is sensible of the degrees both of cold and heat. And, in the winter; we sometimes placed a kind of cap of snow, upon the head of the glass; which has so much increased the cold, even in a snowy season, as to raise the water a few degrees higher, by condensing the air*.

* See Novum Organum, part ii. aph. 13.

2. We above observed, that the air in this glass was dilated a third; and contracted itself as much upon a remission of the heat.

PRECEPT.

1. It deserves to be tried by particular experiments, whether air dilated with heat, might be fixed in its expansion; so as not to endeavour its own restoration and contraction. Take therefore, a strong glass tube, heat it violently, then perfectly close up the orifice, that the air may not contract; and let the glass stand for some days thus closed: afterwards plunge it. still stopt, into water; open it under the water, and observe how much liquor it draws in; or how the quantity is, in proportion to what it would have attracted, if the glass had been directly put into water.*

2. Observe likewise, by the way, with regard to the title of heat and cold, whether air so strongly dilated, and forcibly detained, retains its heat much longer than when the orifice of the glass is left open.

HISTORY.

1. In very clear and cold nights, during the winter, the stars appear larger than in the se-

* The experiment might be better tried in the condenser with strongly compressed air. See Mr. Boyle's Experiments upon the Spring of the Air.

rene nights of summer; which proceeds principally from the general condensation of the air at that time, inclining it more to the nature of water: for all things appear much larger in water.

2. Morning dews are, doubtless, vapours, not perfectly dissipated, and converted into pure air; but hang imperfectly mixed, till by the cold of night, especially in that called the middle region of the air, they are reflected back, and condensed into water.

3. The condensation of rain, snow, and hail, proceeds likewise from the cold of the middle region; which generally coagulates vapours higher up than dews. But here occur two difficulties, which should be carefully examined. The first is, whether the drops of these meteors are congealed and condensed in their fall; or, whether they were first collected into larger masses of water, that hung pendulous in the air, on account of their distance from the earth; and were afterwards broke and reduced to drops, by any violence: for there are certain cataracts, or rains, in the West Indies, which descend so thick and sudden, as if they were poured out of vessels. The other is, whether not only vapours, which were water before; but also a large part of pure and perfect air be not coagulated and

really changed into rain, &c. by the vehement and intense cold of those regions*.

4. In distillations, moisture is first converted into vapour: which being now deserted, through its distance from the fire, dashed against the sides of the distilling vessel, and sometimes cooled by the external application of cold water; restores itself to liquor again. This seems to be a familiar emblem of the process of dew and rain.

5. Some metalline matters, as particularly quicksilver, when made volatile, have a sudden tendency to restore themselves; and greatly affect to meet with a solid body in their way. And hence they easily stick, and easily fall off again; insomuch, that it is sometimes necessary to pursue their fumes, with the fire; and trans-

* It has not hitherto perhaps been evidently manifested by experiment, that air is condensable into water. But the experiment of attracting all the moisture out of a certain quantity of air, as it remains in a close vessel, by means of the common caustic, or other fixed alkaline salt, deserves to be carefully prosecuted. For when this experiment is exactly made; it should seem as if almost the whole weight of the air were acquired by the salt. The vessel should here be large; the scales well made; the salt perfectly dry and hot; and all the parts of the operation performed with care; so as to prevent being imposed upon through oversight.

mit them from one degree of heat to another; as it were in an ascending scale, or series of fires, placed at some distance from one another, about the vessel; lest the fume, after ascending, and being removed from the first fire, should restore itself sooner than it ought.*

6. Such things as melt at the fire, grow dense upon a remission of the heat, and solid as before; which is the case of metals, wax, fat, &c.

7. A fleece of wool gains weight by lying long upon the earth, which could not happen, if some pneumatical matter were not condensed into such as is tangible and ponderous.

8. It was an ancient practice, at sea, to spread and hang out fleeces of wool by night, on the sides of ships; but so as not to touch the water; and by this means to collect and express a sweet water out of them, in the morning; for the service of the voyage.

9. I have found upon trial, that four ounces of wool being fastened to a rope, and let down into a well, fifty six yards deep; but so as to come only within twelve yards of the water; the wool has, in a night's time, acquired the additional weight of an ounce and a drachm: and per-

* As in the preparation of butter of antimony, &c. which stick in the neck of the retort, and require to be melted down, by applying live coals on the outside of the glass.

fect drops of water have appeared to stick on the out-side of the wool; so that one might, in a manner, have washed one's hands therewith. And this I have several times tried, with different increases of weight; but always somewhat considerable.

10. Stone, flint, and marble; as also rails and other wood-work, especially if painted, appear manifestly moist and dewy upon thaws, or in particular seasons, when the wind is southerly; so that they seem to sweat: and may have drops of water brushed off from them.

11. In hoary frosts there is a collection of the hoary matter found froze on the windows of houses; and this to a greater degree on the inside than the outside of the glass.

12. The breath, which at first is but air drawn in, and moistened by a short stay in the cavity of the lungs, appears turned into a kind of dewy substance, upon looking-glasses, gems, sword-blades, and the like polished bodies; and afterwards dissipates, like a fine cloud.

13. Linen is found to contract a moisture within doors; so as to reek before the fire.

14. All powders collect a moisture in the closets or places where they stand close shut up; so as to cling together, or form as it were a mass.

15. Some imagine that the origin of springs,

and sweet waters, is owing to the air shut up, coagulated and condensed in the cavities of the earth; but particularly the cavities of mountains.

16. Mists are imperfect condensations of the air, consisting of a large proportion of air, and a small one of aqueous vapour: and these happen in the winter, about the change of the weather from frost to thaw, or from thaw to frost; but in the summer and the spring, from the expansion of the dew.

PRECEPT.

As the conversion of air into water, would be a thing extremely useful; all the instances having any tendency this way, should be carefully considered: in particular, it should be ascertained, whether the exudations of marble, and the like bodies, in rainy seasons, and southerly winds, are mere condensations of the air, reflected by the hardness and smoothness of the body, like the breath on a looking-glass; or whether they participate at all of the internal pneumatical juice of the stone, &c. Trial may be made of this by laying a cloth upon the stone; for if the stone should sweat in this case also, the exudation must participate of an internal cause*.

* It now seems generally allowed that the moisture in this case proceeds entirely from the air, and not from the

SPECULATION.

The air is converted into water, in the upper regions, seems certain, from the conservation of things; for, doubtless, the moisture of the sea and earth, is converted into pure air, after it has by time, association, and a plenary rarifaction, totally put off the nature of vapour; and therefore, if there was not sometimes a mutual change of air into water, as well as of water into air, there could not be a sufficient stock of new vapours, imperfectly mixed, to supply rains and showers, for refreshing and renewing all the species of bodies; but there must necessarily follow unsupportable drought, and conflagrations, violent winds, and tumefactions of the atmosphere, from a continual multiplication of air.*

HISTORY.

1. Water in freezing does not shrink, but swell in its entire bulk; and yet it suffers a manifest condensation of parts; insomuch that there appear cracks and separations within the body of the ice: and sometimes if the air be per-

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solid bodies; which only condense the dewy vapours floating in the air. But whether there be not also some conversion of the air into water is another question. See the History of Winds, passim. See also the following Speculation.

* Compare this with Sir Isaac Newton's queries to the same purpose, at the end of his Opticks. See also the author's History of Winds, passim.

mitted to enter, something like hairs, strings, and flowers, appear by degrees. Yet ice floats on water: whence it is manifest that the condensation is not total.*

2. Wine freezes slower than water; and spirit of wine does not freeze at all.

3. Mineral acid spirits, and quicksilver, have not hitherto been brought to freeze†.

4. Oils and fats, freeze, and are thereby condensed: but not to a degree of impenetrable hardness.

5. Frost makes the earth concrete together, and renders it dry and hard: and in the northern regions, the poet observes, that metals are frequently observed to crack.‡ And the like we find among ourselves, in tables, or other woodwork; especially where the parts are glewed together. And it is reported, that even nails have, by the contraction of cold, been made to fall from the walls they were drove in.‖

6. Animal bones become more brittle in frosty weather; insomuch that fractures are, at such times, more common, and difficult of cure. In

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* See above Sect. XI.

† Oil of vitriol, if extremely strong, or perfectly dephlegmed, will appear congealed in an intense cold.

‡ Æraque dissiliunt vulgo, vestesque rigescunt.

‖ See Mr. Boyle's History of Cold.

short, all hard bodies become more brittle by cold.

7. Waters, or juices, are manifestly condensed into shining or crystalline stones; as appears in subterraneous caverns seated among rocks, where are found isicles of various forms, like the common; only fixed and stony; hanging pendulous in their slow fall, or descent from the roof or arch; and being congealed in the passage; but whether the matter of them be totally aqueous, or the native juice of the stone, with some other mixture, is a question; especially as gems and crystals often shoot, and rise upwards out of opened rocks, and do not fall or hang pendulous downwards: which is a phenomenon that cannot well be attributed to the water lodged there.*

8. Clay is evidently condensed into stone; as appears from certain large stones composed of little ones, cemented together by a stony matter, as polite and hard as the stone itself: though this condensation seems not to proceed from the sole coldness of the earth; but from assimilation, of which more hereafter.†

9. There are certain waters which condense

* See Mr. Boyle of the Origin and Virtues of Gems; and the account of the Caves Goutiers, given in the French Memoirs.

† See Sect. XVIII.

wood, and other light bodies, into a stony matter; so that the lower part of the body, which was under the water, shall be stone; and that above, remain wood: and hereof I have myself seen instances. This is a particular which should be well enquired into; as it may afford great light in the practical business of condensation.*

PRECEPT.

It is possible that metallic waters, by reason of the density they contract from the metals, may have a petrifying virtue: and of this let trial be made with straw, thick leaves, wood, &c. But we conceive such metallic waters should be chose, as are made by frequently washing, or quenching, metals therein; rather than by solution; lest the corrosive menstruums, which must otherwise be employed, should hinder the condensation.†

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* In particular, let due enquiry be made, whether it is not owing to the insinuation of a petrescent matter, into the pores of the wood; or whether this be a true and proper conversion. See the articles *Alteration*, *Percolation*, *Putrefaction*, and *Transmutation*, in the Sylva Sylvarum.

† Let a proper analysis be made of the water of certain known petrifying springs, or lakes; in order to discover the contents of such waters: from whence artificial petrifying waters might, perhaps, be made in imitation of the natural. There are some accounts in the Philosophical Transactions of such petrifying waters, and petrified substances.

10. In China they have artificial mines of porcellane earth, by burying, at some depth under ground, a certain mass of prepared plaister, or cement; which lying thus buried for about forty years, is converted into porcellane. So that these mines are transmitted, like an estate, from father to son.

11. I have been well assured that an egg, by long lying at the bottom of a moat, was found manifestly petrified; with the colours and distinctions of the shell, white and yolk, still remaining: only the shell was here and there broke, and shone scaly. And I have frequently heard that the white of an egg has been turned to a stony matter; but neither know the truth of the thing, nor the manner of doing it.

12. Doubtless flame, upon being extinguished, is converted into something; viz. an after-fume; which is again converted into soot; but the flame of spirit of wine, and the after-expiration of such pure inflammable substances, should be carefully examined; in order to discover what substance they are condensed into, and what kind of after-exhalation they afford: for it does not appear to be any thing fuliginous; as in the case of flame from oily bodies.* And so much

* See M. Geoffroy's Memoir upon the Method of discovering and ascertaining the Quality of Brandies and Spirit

for the contractions of bodies by actual cold, in air, in water, in liquors, and in flame; whether the contraction were simple, a restoration, a coagulation, or a conversion.

SECT. XVI.

THE HISTORY OF THE CONTRACTIONS OF BODIES BY POTENTIAL COLD.

TRANSITION.

We next proceed to the action opposite to dilatation by potential heat; viz. contraction by potential cold.

1. As the medicinal tables of secondary qualities are to be consulted in the enquiry of potential heat; so are they likewise in that of potential cold: particularly with regard to astringency, revulsion, infraction, inspissation, and stupefaction.

2. Opium, henbane, hemlock, nightshade, mandrake, and the like narcotics, manifestly condense the spirits of animals, turn them back

of Wine; where he has a particular method of burning spirit of wine; so as apparently to resolve a large proportion thereof into water. Memoir. de l'Acad. an. 1718. See also Dr. Stahl's three hundred experiments and observations, printed at Berlin, an. 1731.

upon themselves, stifle and deprive them of motion: and whether they have any effect upon dead bodies, may be tried by steeping flesh in their juices; to see if any blackness or gangreen will ensue; or by soaking seeds and kernels therein; to observe whether it will kill them, and prevent their growing; or again, by besmearing the top of a thermometer, on the inside, with their juices; to discover whether this will, in any measure contract the air.*

3. There are found in the West Indies, even in sandy desarts and very dry places, large canes containing, in every joint, a considerable quantity of sweet water; to the great refreshment of the traveller.

4. There is said to be a certain tree in one of the Canary Islands†, that continually distils water; and has a certain dewy cloud always hanging over it. It were highly worth examining, whether any vegetable has such a potential coldness as to condense air into water. Of this particular, therefore, let diligent enquiry be made.‡

* There seem to be few experiments of this kind extant.

† It is the island Ferro, the most western of the Canaries.

‡ There are two or three accounts of this tree to be found in Purchas. One of them runs thus: "In the island Ferro, they have no other water but that which proceeds in the night from a tree encompassed with a cloud; whence

Though I rather suspect that these trees are no other than the knotted canes above-mentioned.

5. Upon the smooth leaves of certain trees, as those of the oak, that neither drink in nor preserve moisture, there are found in England, sweet, or, as it were, honey-dews, like manna; especially in the month of May: but whether this proceeds from any coagulating virtue in the leaves, or whether the leaves only preserve the dew, is not certain.*

6. There is scarce any substance wherein potential heat is so remarkable as in nitre: for as spices and other bodies, though they have no perceptible heat to the touch, yet they have it to the tongue and the palate; so nitre has a perceptible coldness in the mouth, beyond that of houseleek, or any of the coldest plants: whence nitre seems a fit subject for proving the virtue and efficacy of potential cold.

PRECEPT.

Take, therefore, a small and extremely fine

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water issues, serving the whole island, both men and cattle: a thing notorious, and known to very many." Purchas, vol. ii. page 1673. See also in the same author, the Observations of Sir Richard Hawkins, vol. ii. page 1367, 1368, and 1369, and the note at the bottom.

*Or whether it be not the condensed saccharine juice of the tree, exuding along with the other aqueous juices, and dried by the sun upon the surface of the leaf.

bladder; blow it up; tie it, and bury it in nitre for some days; then take it out; and observe if the bladder be any way shrunk: if it be, conclude that the nitre contracted the air. Let the like experiment be tried with quicksilver, by plunging a bladder therein; the bladder being tied down, to prevent its rising, and to avoid the necessity of keeping it pressed.

HISTORY.

If vinegar be put to ointment of roses, or the like unctuous body; the ointment is so far from being thinned thereby; that on the contrary it becomes more hard and solid.

SECT. XVII.

OF THE CONTRACTIONS OF BODIES BY FLIGHT AND ANTIPERISTASIS.

TRANSITION.

Opposite to the action of dilatation by consent or embrace, is that of contraction by flight and antiperistasis: for as bodies every way open and relax themselves to such as are friendly and agreeable, and even run to meet them; so when they happen upon such as are unfriendly and odious, they avoid them every way; contract and shrink themselves up.

HISTORY.

1. The heat of fire seems to be somewhat con-

densed, and rendered sharper by antiperistasis; as in frosty weather.

On the contrary, in the torrid zone, cold seems to be condensed, by antiperistasis; so that if any one shelters himself under a tree, from the scorching heat of the sun, he presently shivers with cold.

2. This operation by contraction of antiperistasis is not without some pretence of reason, attributed to the middle region of the air; where cold collects and unites itself, to avoid the scattered rays of the sun from above; and the reflected rays from the earth: whence there are great condensations made in that region of rain, snow, hail, &c.

3. It may, with justice be doubted whether opium and other narcotics, stupefy by potential cold; or by putting the spirits to flight: for opium, by the strength of its smell, its bitterness, sudorific virtue, and other signs, seems to have hot parts: but as it may emit a vapour, disagreeable and odious to the spirits; it may every way put them to flight; and so coagulate and stifle them.

SECT. XVIII.

OF THE CONTRACTIONS OF BODIES BY ASSIMILATION, OR CONVERSION INTO A DENSER STATE.

TRANSITION.

OPPOSITE to the action of dilatation by assimilation, and conversion into a rarer body, is the action of contraction by assimilation, and conversion, into a denser: supposing it to be done not by cold, whether actual or potential; but by the power of a more active body, which multiplies itself upon one that is more passive. But assimilation to a state of density is less frequent, and much less powerful than to a state of rarity; because dense bodies are more sluggish, and unactive, than rare ones, in the business of assimilating.

HISTORY.

1. We above observed, that clay intermixed with little stones is condensed into a stony matter.

2. The sides of the cask condense a recrementitious part of wine into tartar.

3. The teeth condense what adheres to them from chewing the food and from the moisture of the mouth into scales; which may be scraped off with an instrument, though they have the hardness of teeth.

4. All hard and solid bodies condense some part of the liquors adhering to them, on the sides, but principally at the bottom.

5. Whatever aliments are converted into a nourished matter, more dense than the matter of the aliment, is plainly condensed in the assimilation; thus the meat and drink of animals is condensed into horn, bone, &c.

SECT. XIX.

OF THE CONTRACTIONS OF BODIES BY EXTERNAL VIOLENCE.

TRANSITION.

Opposite to the action of dilatation by external violence, whether with or against the appetite of the dilated body, is the action of contraction by external violence; when bodies are put under a necessity of giving way to the things that act thereon, and so of compressing themselves.

HISTORY.

1. Air easily suffers some degree of condensation, by external violence, or compression; but will not endure a large one: as appears from stormy winds and earthquakes.

2. If a wooden bucket be inverted, and forced perpendicularly with the hand into water, it will

carry air with it to the bottom; without admitting water into it; except a little about the edges: as will appear by the colour of the wood, which shews the exact measure of the air's compressure withinside. This appears still more eminently in that useful invention the diving-bell, for working under water; being no more than a large concave vessel of wood, filled with air, and made to stand upon three ponderous metalline feet, somewhat below a man's height, in order to sink it. This vessel is let down into the water; and when the divers want to take breath, they stoop, put their heads into the cavity, and there breathe freely. And by this help occasionally, they can continue their work under water for some time; or till the air, part whereof comes out each time the head is thrust in, becomes too little for the purpose.*

3. The rarer bodies are, the easier they contract themselves at first; but the more they are compressed beyond their natural dimensions, the stronger they resist: as is manifest in flame, and condensed air close confined.

4. Flame, though but simply compressed, (even without a blast, as in gunpowder,) rages

* Or else is spoiled by having already served for respiration. See the late improvements of the diving-bell, in the Philosophical Transactions, No. 349.

violently; for example, in reverberatory furnaces, where the flame is checked, confined, beat back, and diverted in its course.

ADMONITION.

Dilatation by diffusion has no reciprocal action opposed to it; because the bodies diffused are not amassed together again, unless by melting; as in the reduction of metals; which we have mentioned above.

SPECULATION.

There is also, perhaps, another kind of contraction of bodies, which is not reciprocal, but positive, and by itself: for we conceive that in the solution of bodies by liquors; as for instance metals, gum, sugar, &c. the body is somewhat received within the liquor, and yet the liquor is not dilated or expanded in bulk, proportionably to what it takes in. And if so, there must be a condensation; because the same space will then contain more matter. It is certain, in the solution of metals, that when once the menstruum is fully saturated, it will operate or dissolve no more. And this kind of condensation, if there be any such, we may call the contraction of bodies by saturation.

PRECEPT.

Compress ashes close together; then pour wa-

ter upon them; and carefully observe how far they shrink, after they have taken in the water; in comparison of the bulk they had before, when mixed only with air.*

OBSERVATIONS.

1. The efficients in the dilatation of bodies, discovered by the preceding enquiry, are the nine following; viz. 1. The introsusception or admission of a foreign body. 2. A natural or preternatural expansion of the native spirit. 3. Fire, or external actual heat; or even a remission of cold. 4. External potential heat, or auxiliary spirits. 5. The release of the spirits from the prisons of the parts. 6. Assimilation, from the prevalence of a rarer, and more active body. 7. Embrace, or the attraction of bodies related. 8. Separation, or external violence: and 9. Diffusion, or a spreading out of the parts.

2. The efficients in the contraction of bodies are eight; viz. 1. Exclusion, or the discharge of a body received. 2. Shrinking, or contraction of the parts, after the spirit is discharged. 3. External actual cold, or even a remission of heat. 4. External potential cold. 5. Flight

* See the Preface to Dr. Hook's Posthumous Works: and Dr. Grew, upon Mixture.

and antiperistasis. 6. Assimilation from the prevalence of a denser and more active body. 7. Compression by external violence: and 8. Saturation, if there be such a thing.

3. The actions of dilatation, 1. by the native spirit. 2. by the release of the spirits; 3. by diffusion; and, 4. The action of contraction by constriction, are without reciprocals; but so are none of the rest.

4. The dilatations by introsusception, and by diffusion, are spurious: so are the contractions by exclusion; as being not substantial but local.

5. Expansion by fire, or heat, without separation is the simplest of all; and performed in a pure pneumatical body, such as the air; where nothing exhales, or subsides; but a mere dilatation is made, to a considerable bulk. Whether there be any thing like this in flame; that is, whether after the first expansion of its kindling, which is considerable, it expands still farther, after it becomes a formed flame, is hard to determine; because of its quick and momentary extinction. But this belongs to the subject of flame.

6. What approaches next to this dilatation in point of simplicity, is the expansion that happens in the melting of metals; or the softening

of iron, wax, &c. some time before any thing becomes volatile and is discharged. This dilatation is secret, and transacted in the cavities of the entire body; without visibly changing or enlarging its dimensions; but as soon as any thing begins to fly off, then the actions become complicate, or partly rarifactive, and partly contractive; so that those contrary actions of the fire, vulgarly observed to harden one thing and soften another,* depend upon this; that in one case the spirit is discharged, and in the other detained.

7. The condensation made by fire, though not spurious, but substantial, is rather a condensation of the parts, than of the whole: for the grosser parts are certainly contracted; yet so as to render the entire body more hollow or porous, and less ponderous.

SECT. XX.

VARIABLE CANONS, OR IMPROVEABLE AXIOMS.

THE total sum of matter in the universe, ever remains the same; and there is no passage, in nature, either from nothing, or to nothing.

* Limus ut hic durescit, & hæc ut Cera liquescti.
Uno eodemque Igni.

Of this original sum, there is more in some bodies, and less in others, under the same dimensions.

A greater and less quantity of matter afford the true criterions, if rightly understood, of density and rarity.

There is a boundary, or limited degree of density and rarity; but not in any subject known to us.

There is an absolute vacuum in nature.

Matter folds and wraps itself up within the bounds of density and rarity; and again, relaxes and unbends itself, without admitting an absolute vacuity.

The differences of density and rarity, in the tangible bodies known to us, do not greatly exceed the proportions of thirty-two to one.

The difference between the rarest tangible body, and the densest pneumatical body, is above a hundred to one.

Flame is rarer than air, and oil than water.

Flame is not rarified air, nor oil rarified water; but they are plainly heterogeneous bodies, without any great relation between them.

The spirits of vegetables and animals are breaths composed of an aerial and flamy pneumatical substance; as their juices are of one that is aqueous and oily.

All tangible bodies, here with us, have a pneu-

matical substance, or spirit, joined to, and included in them.

No spirits, such as those of vegetables and animals, are found loose, and unconfined amongst us; but shut up, and imprisoned in tangible bodies.

Condensation and rarifaction are the proper effects of cold and heat.

Heat operates upon pneumatical bodies by simple expansion.

Heat has two operations upon tangible bodies, and always dilates the pneumatical parts; but sometimes contracts, and sometimes relaxes the gross ones.

It observes this rule; when the spirit of the body is discharged, it contracts, and indurates, but softens and dissolves, when the spirit is detained.

Colliquation begins with expanding the pneumatical parts of the subject; but other dissolutions begin with expanding the gross parts, and setting free the operations of those that are pneumatical.

Next to heat and cold, the most powerful rarifier and condenser of bodies is consent and flight.

Restoration from violence both dilates and condenses, in a contrary tendency to the violence.

Assimilation both dilates and condenses; as the assimilating body is rarer, or denser, than the body assimilated.

The rarer the body, the greater expansion and contraction it is capable of, from external violence, to a certain degree.

If tension, or pressure, exceeds its bounds, in a rare body; such a body frees itself more powerfully, than a dense one; as being more active.

The most powerful expansion, is that of air and flame conjointly.

Dilatation and contraction are but imperfect, where the bodies easily and readily restore themselves.

Density and rarity have a great affinity with gravity and levity.

Man has but little power in the business of condensation, for want of a potent degree of cold.

Age is like a lambent fire, and acts like heat; though in a more exquisite manner.

Age brings bodies either to a state of putrefaction or dryness.*

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* Observe that these canons or axioms are deduced, as corollaries, from the preceding enquiry.

SECT. XXI.

DESIDERATA AND THEIR APPROXIMATIONS.

DESIDERATUM. I.

A method of condensing air into water.

APPROXIMATION.

The approximations here are springs in the cavities of mountains; the exudations of stone; the condensations of the breath into dew; the method of hanging out woolly matters on the sides of ships to collect sweet water at sea; the aqueous meteors, &c.*

II. *A method of increasing the gravity of metals.*

The conversion of iron into copper; the increase of lead in vaults; the conversion of quicksilver into gold; if such things there are.

III. *A method of petrifying earths, and other substances, vegetable or animal.*

Petrifying waters; compounded stones, consisting of little ones crusted together; crystalline isicles in caves; stones in the kidneys, bladder of urine, and gall-bladder; scales of the teeth, &c.

IV. *To discover various uses of the motion of dilatation and contraction in the air, by heat.*

* These particulars are already mentioned in the body of the enquiry.

The thermometer; hero's altar;* the organ made to play by the sun's rays; and the contrivance for imitating the ebbing and flowing of the sea, and rivers.

V. *A method of supplying the limbs of animals, by a proportionate heat, and the detention of the spirit.*

The softening of iron; the softening of wax; and the business of amalgamations. This regards the restoration of youth in old age: for all humectation, besides what proceeds from a detention of the native spirit, seems to be spurious, and of little efficacy.†

ADMONITION.

We here propose but few desiderata, with their practical hints; because the subject is so general and extensive, that it rather serves to inform the judgment, than direct to practice.‡

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* See Sect. IV.

† See the History of Life and Death, passim.

‡ Let it be observed that this is no more than a delineation, or first draught, of the History of Condensation and Rarifaction, that requires to be continued, amended, filled up with instances, transposed and verified, according to the directions of the second part of the Novum Organum; till the canons become stable, and lead, without error, to practice; till the Desiderata here mentioned may be readily supplied, or shown to be impracticable; and till the doctrine and axioms may fully inform, and securely conduct the mind in future enquiries; by way of a general opening and introduction to physics.

PHILOSOPHIA PRIMA:

OR,

A TEMPORARY STRUCTURE

OF

PHILOSOPHY,

RAISED BY THE

Natural, unassisted Powers of the Understanding, and of service only till a genuine and pure Axiomatical Philosophy be procured, according to the Directions of the

NOVUM ORGANUM.

AUTHOR'S

PREFACE.

WE judge him to have been a beneficent man, and a prudent magistrate, who when asked if he had given his citizens the best laws he could, replied, "the best that they would receive." * And certainly, he who is not content with good thoughts alone, which are little better than good dreams, but also desires to obtain his end, and effect his design, must not always chuse the best things; but sometimes prefer the best of such as may be received.

But though we earnestly desire to promote the good of mankind in general, as they are all citizens of the world, yet we think ourselves not at liberty to use this legislative power, or make this prudential choice: and accordingly neither pretend to impose laws upon the understanding, nor upon things themselves: but only as faithful secretaries, receive and write down such laws as are published by the voice of nature. And therefore, whether such laws shall happen to please or displease, and so be received by the voice of opinion, we are resolved to execute our trust.

* The saying of Solon, with regard to the Athenians.

And indeed we conceive hopes that there are at present, and will through succeeding ages, arise, men of eminence, capable of receiving, procuring, and delivering the best things of all; and solicitous in cultivating and bringing them to perfection; whence we are determined to continue our endeavours after these better gifts; opening the fountains both of things and uses; and on all sides searching out indications of the right ways.

But whilst we thus strenuously pursue the greater matters, we do not disregard the less; especially as these are nearer hand, but those lie farther off; for we duly regard whatever may be of general use; and promote the common good. And therefore, though, in our own opinion, we lay better things before mankind than either the ancient, or those at present received; yet we are far from lessening these latter in the public esteem: but desire that even these should be improved, enlarged, and prized as they deserve. For it is no part of our intention, to lead all men totally, or any of them immediately away from the things at present authorized and believed. But as an arrow in shooting, whirls round its axis all the time of its progressive motion, and thus helps itself forwards; so whilst we tend to our mark, we desire to roll round in the things now commonly known and received. And thus we candidly and ingenuously make use of the assistance of common reason, and the vulgar demonstrations; though we disallow their sway, or absolute authority: but, with the same right as the rest of mankind, deliver such things as we have discovered, and approved, by the ordinary means: for such things may, doubtless, have a great share of truth and utility.*

* This passage and the following regard the author's new method of induction, and investigation of the forms of things, as laid down and exemplified in the Second Part of his Novum Organum.

By this procedure, however, we mean not, in the least, to derogate from what we have all along said, of the insufficiency of the unassisted natural reason, and the demonstrations of the ancients; but only lend out these things to the world for a time, to accommodate those who, through a want of abilities, or through multiplicity of other affairs have just excuse for confining their contemplations within the old beaten paths and provinces of the sciences, or at least, within the confines thereof; and again, to serve such as, according to our indications and directions, shall enter into, and pursue our true method of interpreting nature: thus setting up for them inns by the way, for their ease, support, and refreshment: whilst at the same time, we in some degree promote the felicity of mankind; and afford a large supply of matter to such minds as have a somewhat closer affinity and connection with nature. Though this we no way hope to do, on account of any extraordinary talent, or any uncommon reliance we have upon ourselves.

On the other hand, if any person of a common capacity, but of a ripe judgment, would lay aside the idols of his own mind, resolve to begin his enquiries anew, and with attention, diligence, and freedom, converse among realities, or the facts and experiments of natural history; he might thus, doubtless, penetrate much farther into nature, by the sole proper and genuine powers of the mind, and by his own mere natural thoughts and apprehensions, than by reading all the authors that have wrote, or by indulging himself in abstract contemplations, or by pursuing and repeating the most rigorous and assiduous disputations: and this though he were not to use any of our machinery, or contrivances, to assist his understanding; nor was ac-

quainted with the true form of induction and interpretation.* We, therefore, hope that something of this kind may happen to ourselves; especially as we have already had some experience in the business of interpreting nature; which may probably correct and change the perverse habit and bent of the mind.†

This, however, must not be so understood, as if we required that assent to our own doctrines and opinions, which we refuse to the ancients: for we openly profess and declare, that we will by no means abide by the things we shall here deliver; whatsoever they may prove: and this purely to reserve every thing, as it were, entire, for our secondary, inductive, and more perfect philosophy.

We think proper in the work itself, to deliver our thoughts loose and free; without binding them up into method: because this form best suits the young sciences, that are but just sprouting a-new from their roots; and has no tendency to build up an art, by the cementing of things together; but leaves, as it ought for the present, every subject unlimited, and open to farther enquiry.

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* As delivered in the Novum Organum

† Which it has to idols, abstract speculations, generals, &c. See the Novum Organum.

AN

ESSAY

Towards a Scientifical History of

NATURAL PHILOSOPHY;

FROM THE

PRIMITIVE TIMES TO THE PRESENT.

Deduced by way of Explanation upon the ancient Fable of Cupid *.

SECT. I.

THE PHILOSOPHY OF SUCH AS HOLD ONE PRINCIPLE OF ALL THINGS.

WHAT the ancients relate of Cupid or Love, cannot coincide in the same person. And indeed they made two Cupids, extremely differing from each other; the first being called the eldest of the gods, and the second their youngest

* This is an unfinished posthumous piece, published by Gruter among the Scripta; and does not execute half of his original plan: which was to explain the whole doctrine of all the ancient philosophers, concerning the first principles of things; and set that obscure affair in a genuine light; that the grand work of experimental philosophy might go on, without the interruption of any fantastical theory, scepticism, or a disbelief of the senses. And tho-

son: but our present business is with the former. The elder Cupid is said to be prior to all things, except chaos, which is made coeval with him. He is introduced absolutely without parent: but by mixture with Cœlum, he is said to have begot the gods, and every thing else. Some, however, relate that he was produced from an egg, hatched by Nox. He has different attributes assigned him; as those of being always a child, blind, naked, winged, and an archer. His principal and peculiar power is that of uniting bodies. And the keys of the sky, the sea, and the earth, are said to be his.*

This fable seems, in the narrow compass of a parable, to deliver a philosophical account of the principles of all things, and the origin of the world, not greatly differing from that of Democritus; only the former appears somewhat more sober, exact, and pure. For though Democritus was a very acute and industrious philosopher; yet his contemplations run into extrava-

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the author has left the undertaking unfinished, yet there is enough done, to set even an ordinary capacity in the way of executing it; which perhaps requires rather plain natural sense, diligence, and application, than bright parts, or a penetrating genius.

* See the same fable in the author's piece de Sapientia Veterum.

gance; and did not each other sort with or sufficiently support themselves. And even the points here couched in the fable, though somewhat more correct, are but such as may seem to have proceeded from the understanding left to itself; and not successively, or gradually assisted by experience*. And this we judge to be an error that prevailed, even in the first ages of the world.

We must also observe, that the things wrapt up in this fable are but the conclusions of human reason, and the dictates of the sense, whose defective and ceasing oracles are now justly rejected; since better, and more certain accounts are given us by revelation. Chaos, therefore, which was coeval with Cupid, denotes a rude heap, or collection, of matter: but the matter itself, together with its power, its nature, and the principles of things, are shadowed out in the person of Cupid; who is introduced without parent, that is, without cause; for causes are as the parents of effects. And it is common, in figurative speech, to denote the cause and effect, by the words parent and offspring. But for the first matter, and its particular energy and action; it could have no cause in nature: (for in

* According to the method delivered in the second part of the Novum Organum.

assigning philosophical causes we always except God) as nothing existed before it. Matter, therefore, had no efficient, nor any thing better known or closer linked to nature, than itself; and consequently has neither genius nor form*. And therefore, whatever, this matter be, together with its power and efficacy, it is a positive and absurd thing; to be taken just as we find it: for it cannot be judged of by any previous notion or pre-conception. And if its modus could be known; this would not be from its cause: as it is, next after God, the cause of causes, and itself without a cause. For there is a true and certain limitation of causes in nature; and it would be as absurd and unphilosophical to require them, when we arrive at the ultimate powers, and positive laws of nature; as not to require them in things of a subordinate kind. Cu-

* Whence the nature of matter can never be understood by man; but we are obliged to take it as our senses represent it. And it might be for the advantage of philosophy to do this, without indulging endless speculations about its cause, the reality of its existence, the possibility of its thinking, &c. Instead whereof, the proper office of philosophy is, to discover the laws, the motions, the modifications, the transformations and changes of matter: but for knowing its nature, or real form, if it had any; this would imply a possibility in man to create matter, which involves a contradiction. See Novum Organum, part ii. aph. 4. and the History of Condensation and Rarifaction.

pid, therefore, is in the fable wisely supposed to be causeless.

Nor is this an affair of slight consequence; but of very great importance: for philosophy has been corrupted from no quarter more than from this enquiry after Cupid's parents; that is, from philosophers not receiving and admitting the principles of things, as they are found in nature, for a certain positive point, upon the attestation of experience; but they have rather derived and deduced them by the laws of disputation, or petty logical arguments, mathematical conclusions, vulgar notions, and the like excursions of the mind, beyond all the limits of truth and nature. A philosopher, therefore, should constantly bear in mind, that Cupid is parentless; to prevent the understanding from turning aside to vanity, and empty speculation: because the human mind is extremely apt to run into these general notions; so as to abuse both itself and things; and whilst it endeavours to go forwards, comes back to matters that lay nearer at hand. For as the mind, by reason of its own narrowness, is most accustomed to be moved by such things as occur familiarly to it, and have a power at once to strike and enter the imagination; it happens that when it extends itself to those things which are most general in experience, and yet will not rest satisfied in them; but still endeavours after some-

what better known; it falls upon such things as have the most affected, or ensnared it; and absurdly imagines that these are more demonstrative, and nearer approaching to causes, than those generals it was not content with*.

So much for the first existence, and native power of matter: we come next to the modus of the thing. And this, likewise is very obscure; as the fable elegantly denotes, by making Cupid proceed from an egg hatched by Nox. The sacred philosopher pronounces, that God has made every thing beautiful in its season; and given the world up to the disputes of men; but that man cannot find out the works which the Lord has wrought, from the beginning up to the end. For the highest law of existence and nature, which determines and runs through all the changes of things; (here expressed by the works which the Lord has wrought from the beginning up to the end) or the power imposed by God upon the primitive particles of matter; from the combination whereof proceeds all the variety of things; may be seen darkly; but can scarce be clearly comprehended by the thoughts of men. And this fiction concerning the egg of Nox, is

* Such is the process of the mind when it leaves experience and sense, to wander through the maze of general, abstract notions. See the Novum Organum.

aptly referred to the kind of demonstration whereby Cupid* is brought to light: for those things which are concluded by affirmatives, seem to be the births of light; but those concluded by negatives and exclusions, are educed and forced, as it were, out of darkness and night.† And this Cupid is truly an egg laid by Nox; as all the knowledge we have concerning the original law imposed upon matter, proceeds by exclusions and negatives. But all proof made by exclusion, is only a kind of night, with regard to what is included. Whence Democritus did well to declare that his atoms, or seeds, and their virtue, were like no kind of thing which could fall under the senses; and pronounced them perfectly invisible, secret, and concealed by nature. ‡ Atoms, therefore, are neither like sparks of fire, drops of water, bubbles of air, grains of dust; nor the fine part of the spirit of æther; nor is their virtue and form either gravity or levity, heat or cold, density or rarity, hardness or softness, as in the case of larger bodies; since all these, and the like properties, are compounded

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* Viz, The laws of matter, and its motions.

† See the Novum Organum, part ii. sect. I. aph. 5.

‡ ——— Neque sunt igni simulata, neq'; ullæ
Præterea rei, quæ corpora mittere possit
Sensibus, and nostros adjectu tangere tactus.

and made up of several. Neither, again, is the natural motion of atoms, that of descent or ascent, that of expansion and contraction, that of expulsion and connexion, that of rotation, or any other motion of the larger bodies simply. Yet in the bodies of these atoms are the elements of all bodies; and in their motion and virtue, reside the beginnings of all motions and virtues. But here in the motion of atoms compared with the motion of larger bodies, the philosophy of the fable seems different from that of Democritus; who does not only disagree with the fable, but also with himself; so as almost to speak contradictory in what he farther delivers upon this subject. For he ought to have attributed a heterogeniety of motion to his atoms, no less than a heterogeniety of substance and energy: but he has singled out two motions from the motions of the larger bodies, viz. that of the descent of heavy ones, and the ascent of light ones, and communicated them to his primitive atoms: whereas the fable throughout maintains a heterogeniety, and exclusion, as well in substance as in motion.

Again:

Atq; primordia gignundis in rebus oportet
Naturam clandestinam cæcamq; adhibere;
Emineat ne quid, quod contra pugnet et obstet.

The fable farther intimates, that there is some end and measure of these exclusions; or that Nox does not continue brooding for ever. And certainly it is the property of God alone, when we enquire into his nature by means of the senses not to need exclusions for determining affirmatives.* But the case is different in men; as after due exclusions and negations there is somewhat affirmed, determined, and excluded, to them; like an egg laid after a timely brooding and waiting. And not only the egg is thus laid by Nox; but also the person of Cupid is hatched from the egg: that is, not only a certain notion of the thing may be drawn and extracted from ignorance, but also one that is distinct and clear.† And thus much for that kind of demonstration concerning the first matter; which is a demonstration suited to men, and, in our judgment, corresponds extremely to the sense of the fable.

We next proceed to Cupid himself, or the first matter, together with its properties; which seem

* The forms of things lying open to him. See Novum Organum, part ii. aph. 15.

† The whole of this explanation seems no more than the method of investigating the forms of things, as delivered and exemplified in the second part of the Novum Organum. See aph. 10, 11, 12, 13, &c. of that part.

enveloped in darkness and night; to find what light the fable will afford us herein. But we are well aware that opinions of this kind enter the mind with difficulty, and seem almost incredible, or shocking to the sense and thoughts of men: yet we may plainly perceive, that some attempt has been made in this way, by the atomical philosophy of Democritus; which proving subtile, penetrating deep into nature, and lying remote from common notions, was looked upon as a childish thing by the vulgar; and being also tossed about by the winds of other philosophies, which were better suited to vulgar capacities, it is thus in a manner extinguished and lost. And yet Democritus flourished with great admiration and applause in his own times; and by reason of his universal knowledge was called Pentathlus*; and by the general consent of other philosophers, he was allowed a great naturalist; so that he obtained the name of Magus†. Nor could the violent contests and fierce opposition of Aristotle, (who, with the Ottoman temper, thought his own philosophy would never reign

* As if he had understood the whole circle of arts and sciences: Pentathlus literally signifying a person who performs the five exercises of running, leaping, darting, wrestling, and throwing the quoit.

† Or natural magician, in the honourable sense of the word.

secure, till he had murdered his competitors; and who tells us plainly, that he was determined to cut off all further occasion of doubting); nor even the majesty, and solemn gravity of Plato, totally abolish this philosophy of Democritus: but whilst the doctrine of Aristotle and Plato were, with great noise and pedantical pomp, celebrated and resounded in the schools; this philosophy of Democritus was held in great esteem by the wiser sort, who entered deep into the silent and less obvious kind of contemplations. It is certain, that in the times of the Roman learning, the philosophy of Democritus was still in being, and admired; for Cicero every where makes mention of him with great encomiums; and Juvenal, not long after, gives him a high character, after the manner of the poets, who usually speak the judgment of their own times*. It was not, therefore, Aristotle or Plato, but Gensericus and Attila, and the barbarians, that ruined this philosophy. And indeed when all human learning was shipwrecked, those planks of Aristotelian and Platonic philosophy were preserved, and handed down to us, as a light and tumid matter; whilst the more solid parts of

* —— Cujus prudentia monstrat
Magnos posse viros, & magna exempla daturos,
Vervecum in patria, crassoque sub aere, nasci.

knowledge sunk, and are almost buried in oblivion. But the philosophy of Democritus seems to us worthy of being preserved from neglect; especially since, in numerous particulars, it agrees with the venerable doctrine of the earliest ages*.

In the first place therefore, Cupid is described as a person to whom are attributed nakedness, infancy, wings, arrows, and other things; to which we shall speak severally and in order.† But previous thereto it must be observed, that the ancients laid down their first matter, which they made the principle of all things, as a matter formed and endowed with properties and virtues; and not as an abstract, potential, and uninformed mass. And certainly such a despoiled and passive matter, seems to be nothing more than a mere fiction of the human mind; arising from hence, that the mind gives the greatest stress

* See the Novum Organum, part i. aph. 71, 72, &c.

† The piece, we before observed, is imperfect, so that only the first of these attributes of Cupid is here spoke to; but what is wanting may, in some measure, be supplied from the author's other piece, de Sapientia Veterum; especially where the fables of Cupid, of Cœlum, and of Pan, are explained. This philosophical comment upon the fable of Cupid, was intended to be succeeded by another upon the fable of Cœlum; which would have rendered the design complete.

to the things it imbibes the strongest, and wherewith it is most affected: whence it comes to pass that what men usually call forms*, may seem to have a truer existence than either matter or action; because matter is a dark, and action an unstable thing: and again, because matter is not so strongly impressed upon the mind, nor action always inherent; whilst these phantoms of forms are, on the contrary, thought to be both manifest and constant; insomuch that the first common matter is looked upon but as an accessary or support; and all action but as an emanation, of the form: so that the pre-eminence is absolutely attributed to forms. And this seems to have been the origin and foundation of the kingdom of forms and ideas in things; viz. the superaddition of a certain phantastical and imaginary matter. These phantastical notions have been fed by superstition; which is generally the attendant of error and extravagance. Abstract ideas have been also introduced, and their dignity exalted with as much confidence and authority, that the dreaming part of mankind has, in a manner, prevailed over the waking. But these phantoms now appear to be almost vanished;

* Viz. Abstract or Aristotelian forms; not the forms of the author, which are determined in matter. See Novum Organum, part ii. aph. 1, 4, 10, 13, 15, &c.

only certain writers of our time, have endeavoured to prop them up, as they were tumbling, and to fix them upon their basis again; but doubtless the undertaking is more adventurous than useful. And were it not for prejudice, every man would soon perceive how irrational it is to make abstract matter a principle: for though they assert the actual existence of separate forms; yet no one asserts the separate existence of matter; not even of those who make it a principle. And it seems absurd, preposterous, and incongruous, to the enquiry after principles, to raise essences from phantastical or notional things. For the point is not how we may most commodiously receive into our thoughts, or distinguish the nature of essences; but what are in reality the primary and most simple essences; from which all other things proceed: for the first essence must no less really exist, than those which flow from it; but rather more: since this is self-existent, whereas the others only exist by its means.*

Indeed, what we find said about abstract matter, is not much better than to assert that the world, and all things, are made of catagories,

* See the true doctrine and investigation of forms explained in the Novum Organum, part ii, sect. i. throughout.

and such logical notions, as if these were principles: for it is almost the same to say, that the world consists of matter, form, and privation; as that it consists of substance and contrary qualities. But nearly all the ancients, as Empedocles, Anaxagoras, Anaximenes, Heraclitus, and Democritus, though they differed in other respects about the first matter; yet agreed in this, that it was an active matter, of some form, that had a power of dispensing its form, and a principle of motion within itself. Nor can any one possibly think otherwise, who does not plainly desert experience. All these philosophers, therefore, submitted their minds to things.

But Plato subjected the world to thought; and Aristotle subjected even thought to words; the whole bent and study of men then tending to dispute, discourse and reasoning; with an utter neglect of all severe and rigorous enquiry after truth.* Whence the doctrines of this kind are rather to be censured in the lump, than severally confuted; as being the doctrines of such men as chose to talk a great deal, and understand but little. And to say the truth, this abstract matter is entirely a matter of dispute; but not the matter of the universe. And he who would philosophize in a due and proper manner, must assect

* Suppose according to the rule of the Novum Organum.

nature; but not abstract her, as they are obliged to do, who will not dissect her. And thus we must necessarily lay down, 1. a first matter, joined with 2. a first form, and also 3. with a first principle of motion, as it is found. For the abstraction of motion has also produced infinite phantastical conceits, about souls, life, and the like; as if these could not be owing to matter and form; but must needs depend upon separate principles of their own. These three things should not be separated, but only distinguished; and matter, whatever it is, must be laid down so endowed, prepared and formed, that all virtues, substances, actions, and natural motions may be the consequence and emanations thereof. And let no one apprehend that things will, upon this footing, languish and become torpid; or that the variety we find in the universe cannot hence be explained; for we shall shew the contrary hereafter.

And that the first matter has some form, is indicated by the fable in making Cupid a person; so that though the whole mass of matter were at first uninformed and rude; which is represented by Chaos; yet Cupid is formed and personified. And this account excellently agrees with sacred writ; where we read, that "God in the beginning created," not a confused, uninformed mass of matter, but "heaven and earth." To this

account, however, is annexed some description of the state of things before the six days work; where distinct mention is made of earth and water; which are names of things already formed; yet the mass still remained uninformed, in its whole.

But though the fable introduces Cupid personified, it still leaves him naked: and therefore, next after those who would introduce abstract matter, they err, in the contrary extreme, who introduce it clothed. Somewhat of this subject we have touched above, in laying down such demonstrations as are suitable to a first matter; the heterogenieties introduced wherein, we have also spoke to, in some respect; but this is the proper place for treating them. We must, therefore, here enquire, among such as place the principles of things in matter formed, who they are that have attributed a native, naked form to matter; and who have introduced it covered and clothed.

There are four different opinions relating to this affair. The first is that of those who assert some one thing to be the principle of all things; but constitute a diversity of substances in the indeterminate, and dispensible nature of that principle. The second is that of those who make the principle of things to be one fixed and invariable substance; and derive the diversities of bodies from the different magnitudes, figures, and

positions of this principle. A third sort constitute several principles of things; and place the diversity of bodies in the tempering and mixing thereof. And the fourth sort are those who make infinite, or at least, numerous principles of things; but suppose them specificated, and fashioned: and these have no occasion to invent any thing else for giving a manifold variety; as they have already split and divided nature from the beginning. But of these four sects we judge that only the second exhibits Cupid native and undressed. For the first introduces him as it were veiled; the third vested; and the fourth cloaked, or wrapt up in a mantle, and almost masked. We shall speak a little to each of them, the better to explain the fable.

1. And first, we find none of those who constitute one principle of things, that affirm this principle to be the earth: for the quiet, languid and unactive nature thereof, passively receiving the influences of the heavens, of heat, and of other things, has hindered such a thought from entering into any one's mind. And yet the earliest mythology, or wisdom of the ancients, places Terra next after Chaos; and makes it first the parent, and then the consort of Cœlum: from which conjunction all things proceeded. But this is not to be understood, as if the ancients ever made the earth a principle of beings; but

only a principle, or rather the origin, of a structure, or system, of things. We shall therefore refer the prosecution of this affair to the following fable of Cœlum; under which we propose to enquire into the origin of things: this latter being an enquiry posterior to that of principles.*

But Thales makes water the principle of all things, from observing that matter was chiefly dispensed out in moisture, and moisture dispersed in water. And he judged it not improper to lay that down for the principle of things, in which their virtues, powers, vigour, and especially the elements of their generation increase and repair, are principally found. Thus the seed of animals he observed is moist; and that the seeds and kernels of plants, (so long as they continue in a growing state and unexhausted) are soft and tender. Metals likewise melt, and appear but as concreted juices of the earth; or rather as certain concretions of the waters of the mine.† The earth itself is made fruitful, refreshed and recruited by rains, and rivers: and earth and mud may seem to be only the fæces and sediment of

* This fable of Cœlum, was not, as we above observed, explained in the large manner here proposed; but stands, in a contracted view, at the entrance of his piece de Sapientia Veterum.

† This is a matter of deep speculation and enquiry. See Becher's Physica Subterranea.

water. Air appears still plainer to be but an expiration, and expansion of water.* And even fire itself cannot be supposed to exist, or be fed and supported without moisture. For that fat moisture, which is the support and life of flame and fire, may seem but a certain ripeness and thorough concoction of water.† Again, the body and bulk of water is diffused, as a common matter, throughout this lower world. The earth is every where watered and encircled by the ocean. There is an immense quantity of sweet water in the subterraneal regions; whence fountains and rivers, like so many veins in the body, convey water over the surface, and through the entrails of the globe. In the regions of the atmosphere there are prodigious collections of water, and vapour, that seem to supply a new fund thereof; and recruit, refresh, and enliven all the waters, and the ocean below. Nay, this philosopher went so far, that he even supposed the celestial fires were continually fed with these waters and vapours; as conceiving they could not subsist without aliment, nor derive it from any thing else. And for the figure of the particles of wa-

* See the author's History of Winds, passim.

† Some of Mr. Boyle's experiments appear to confirm, or strengthen, this supposition. See his Sceptical Chemist. See also Becher and Stahl.

ter, he saw by drops, that it was round, or spherical, like the universe. He also observed that water had an undulation, and this even in air and flame: and lastly, that it had a due disposition to motion, neither too languid nor too quick; and that the generation of fish and fowl was extremely numerous.*

But Anaximenes made the air to be the sole principle of all things. But if bulk is to be regarded in constituting the principles of things, air seems to possess a very large part of the universe. And if there be no separating vacuum, or if we reject that superstitious notion of the heterogeniety betwixt the celestial and sublunary bodies, the whole space that reaches from the globe of the earth to the extremity of the heavens, and is neither occupied by stars nor meteors, may seem to be filled with an aerial substance. But the terrestrial globe is no more than a speck or physical point compared with the heavens, that surround it: and in the æther itself, how small a portion is spangled with stars. Near to the earth they appear but very few; and

* And thus the point might seem, in a manner, discovered and settled by an induction of particulars. But inductions of particulars made on one side only, are very fallacious; and in no respect to be trusted. And yet most philosophies are of this kind. See the Novum Organum, passim.

higher up, though their number indeed be great, yet all the space they possess seems inconsiderable with respect to the interstellar regions; insomuch that they may all appear as it were floating in an immense ocean of fine air, or æther. On the other hand, there is a large quantity of air and spirit lodged in the water, and caverns of the earth; from whence the waters may be said to receive their fluidity. Sometimes also the air and spirit swell or expand themselves; and may thus escape through the pores of the earth: but tremblings and earthquakes are esteemed evident signs of wind and air pent up in the earth's bowels.

And if a certain middle nature be required in principles, to render them susceptible of such a vast variety, this property seems to be found perfect in the air. For the air appears to be the common link and cement of things; not only because it is every where at hand, and ready to succeed and fill up vacuities; but much more because it seems to be of a neutral, indifferent, and indeterminate nature. For air is that which receives and transmits darkness, light, and all the tinctures and shades of colours and diminutions of light; and by its curious undulating motion distinguishes tones, voices, the notes of music, and even articulate sounds; and without confusion, distinctly conveys all the variety of smells,

not only those general ones of sweet and fetid, dull and brisk, &c. but also the proper and specific odours of things, as of each particular flower, and all the odorous tribe of bodies. Again, the air remains neutral and indifferent to those great and powerful qualities of heat and cold, dryness, and moisture; and in it are at once suspended and conveyed aqueous vapours, unctuous exhalations, the spirits of salts, the fumes of metals, &c. all separate and unconfounded. Lastly, air is the fluid wherein the rays and influences of the celestial bodies, and the more latent agreements and disagreements of things, secretly reign and act; as if the atmosphere were a second chaos, wherein the seeds of so many things have their effects, their courses, trials, wanderings, and changes.

In short, if we consider the generating or vivifying power in things, which may lead to, and manifest their principle; here again the air will appear excellently qualified: insomuch that the words air, spirit, and soul, are sometimes confounded, and used for the same thing; and this not without reason; as respiration may seem to be an inseparable attendant upon all perfect states of life; so that, excepting the first rudiments of life in eggs, and embryos, even fish require the use of air, and are suffocated for want of it, when the surface of the water remains long

frozen. And fire itself, unless animated by the air around it, dies, and may seem to be nothing more than air ground together, irritated, and kindled: so on the other hand, water may seem to be air condensed and shrunk within itself. Lastly, the earth may perpetually exhale air; so that air need not pass through the state of water in order to obtain its natural form.

Heraclitus, with greater subtilty, but less probability on his side, makes fire the principle of all things; not looking out for a middle nature, which is usually vague and corruptible; but for a high and perfect one, which might prove a certain limit to corruption and change. For he saw there was a great variety and disturbance in solid and consistent bodies; which may be organical, or like machines, that receive innumerable variations even from figure; as appears in the bodies of plants and animals. And even such of these bodies as are not organical, will, if narrowly looked into, be found very dissimilar. For there is a great dissimilarity between those parts of animals which are called similar; such as the brain, the crystalline humour, the albugineous coat of the eye, bone, membrane, cartilage, nerve, vein, flesh, fat, marrow, blood, &c. And so again among the parts of vegetables, as the root, bark, stem, leaf, flower, seed, &c. Fossils are certainly not organical; yet

appear variously mixed in one and the same species; and exhibit a very copious variety in respect of one another. Whence this extensive foundation of diversity in bodies, and this large apparatus, seems to be laid in a solid and consistent nature.

But in the bodies of liquors there seems to be no organical structure. For there appears to be no animal or plant, in a body merely fluid: so that this most extensive variety is denied to, and cut off from the nature of fluidity. It however remains possessed of a considerable variety, as is manifest from so large a diversity of fusible bodies, juices, distilled liquors and the like. But the point of variety is reduced to a much narrower compass in the mass of air, and pneumatical bodies; and obscured with a promiscuous similitude of things. It is certain that the difference of colours and tastes, whereby liquors are sometimes distinguished, is here absolutely wanting; but the impression of smell, and some other things remain; though but transiently, confusedly, and in a less adhesible manner: so that, universally, the nearer bodies approach to the nature of fire, the more they lose of their variety. And after they once put on the nature of fire, in a pure, rectified state; they lose all that was organical, all their distinguishing properties, and all their dissimilarity. And here

nature seems to meet, and unite, as it were, in one pyramidal vortex; and to have attained the ultimate end of its peculiar action. Whence this philosopher called inflammation, or ignation by the name of peace, because it settled and quieted nature, or reduced her to a uniformity; but generation he called by the name of war, because it produced multiplicity and variety. And in order to give some explanation how this was brought about, or how things should from variety be reduced to uniformity; and from uniformity to variety; like the ebbing and flowing of the tide; he thought proper to make fire condensable and rarifiable: but so that its rarifaction, in ascending towards a fiery nature, should be the direct and progressive action of nature; but the condensation, a kind of retrogradation, desertion, or falling back from nature: and both these he thought happened by a certain fatality, at certain periods, in the general mass of things: so that at one time or other, the world itself, when its period was run, should be set on fire, and afterwards renewed, and so pass through successive revolutions of burning and regeneration, to perpetuity.

And if we attentively look into the remaining historical scraps and fragments of this philosopher's doctrine, he will be found to have made the burning and quenching happen in a different order. For in the series of burning he

differed not at all from the common notions upon that head; making the progress of the rarifaction and expansion, to be from earth to water, from water to air, and from air to fire: but in the descending scale he has perfectly inverted the order; and asserted that fire by its extinction produces earth, or certain fæces or ashes; that these ashes conceive and collect moisture; whence there ensues a flood of water; which again shall emit and breathe out air: so that the change from fire to earth shall be sudden and hasty, not gradual.

And these, or perhaps somewhat better, were the thoughts of those who constituted some one thing the principle of all others; considering nature simply, and not contentiously. And they are to be commended for giving Cupid but a single garment; which is the next degree to leaving him naked; especially since this garment, as we before observed, is but a kind of a fine veil, not wove gross and thick. By the cloathing of Cupid we understand the attributing of any form to the first matter, that may be asserted substantially homogeneral with the form of any one secondary essence. And as to the assertions above laid down, from three eminent philosophers of antiquity, with regard to water, air, and fire, it is easy to confute them severally; the foundations they rest on being not more

firmly laid: but as there appears no reason for discussing each point by itself, we shall only consider what they have said in the general.

First, therefore, these ancient sages seem in their enquiry after principles, not to have proceeded in any very exact manner; but only from amongst apparent, obvious and manifest bodies, to have sought out for the most excellent, and to have constituted what they thought so qualified, the principle of all things; and this by the way of eminence, not in the way of precise truth and reality; for they imagined that such a pre-eminent nature was alone worthy to be called what it appears to be; but for other things they conceived them to be of this same nature at the bottom, though it did not appear: whence they may either seem to have spoke figuratively, or else like men under some incantation or prejudice; wherein the stronger impression draws every thing to itself. But a true philosopher must be equal and indifferent to all particulars; and lay down such principles of things as shall agree even with all the smallest, least frequent, and most deserted or unregarded natures; and not only with the greatest, the most numerous, and most powerful. For although men principally admire such shings as occur most strong and lively to themselves; yet the bosom of nature is open to all things.

But if they held their principles, not by way of eminence, but in simplicity; they certainly seem to have fallen upon a very hard metaphor, or figure of speech, which renders their positions plainly equivocal; since what they assert cannot be truly said of natural fire, of natural air; or natural water; but must be understood of certain phantastical and notional things, which retain those names, without the signification. They also seem driven to the like distress with the assertors of abstract matter: for as these absolutely introduce a potential and phantastical matter; the former do it likewise in part. They also, in some respect, lay down a formed and actual matter for their principle; but in other respects make it only potential: yet they seem to gain nothing by thus asserting one single principle, more than those who assert abstract matter for their principle; except in this, that they produce an object for the human understanding, or a thing whereon the thoughts may dwell and be more fixed: so that the notion of their principle proves somewhat fuller; whereas all those of the rest are abstruse and harsh. The truth is, predicaments had not at that time mounted the throne; so as to conceal the principle of abstract matter, under the guard and custody of the predicament of substance. And therefore no man durst then attempt to feign, or

conjure up, any perfectly phantastical matter; but they delivered their principles according to the evidence of sense; and made them some real being: though indeed they took a liberty of dispensing it out in a phantastical manner. For they neither found, nor could invent, by what appetite or incitement; by what method, process, or inducement; their principle should degenerate from itself; and again return to its nature. But as there appears, through the universe, such armies of contraries, in point of density, rarity, heat, cold, transparency, opacity, animation, inanimation, and numerous other properties; which oppose, deprive and destroy each other; to conceive that all these should flow from some one certain fountain of a real material substance, and yet not shew in what manner it happened, may seem like giving a lame and benumbed theory, and deserting the enquiry. For if the fact itself be evident to the senses, it must be admitted; though the manner of it remains concealed and unknown. On the other hand, if any probable and adequate solution should, by the force of reason, be discovered, perhaps some of the appearances might be given up: but it can never be required that we should assent to those things, the existence whereof is neither manifest to the senses, nor the explanations of them rendered probable by reason.

Again, if there was any one principle of all things, it should have a certain visible mark, or a kind of superiority and pre-eminence in all things; at least no principiated body should be found directly opposite to its principle. Nay, such a principle ought to appear in the midst of things, that they might commodiously participate thereof, and be diffused around it: but there is nothing of this kind found in their principles. For the earth, which is cut off and excluded from the honour of a principle, seems to receive and cherish natures that are opposite to the three above-mentioned principles. Thus to the noble and shining nature of fire, it opposes the natures of rest and opacity; to the rarity and softness of air, it, in like manner, opposes density and hardness; and to the humidity and flowing nature of water, it opposes dryness, asperity, rigidity, and fixedness: nay, the earth also possesses the middle place, as if it had thrust away the rest.

Lastly, if there was one single principle of all things, it ought to contribute equally as well to the generation as to the dissolution of them: for it is the nature of a principle, that things should be resolved into it, as well as that things should be generated from it. But this is not here the case; since air and fire seem unfit to afford the matter of generation; and are rather prepar-

to receive the resolution of things. Water, on the contrary is generative and alimental; but more averse and unfavourable to resolution or restoration: as would plainly appear, if rain were to cease for any long time. And even putrefaction itself, no way reduces things to crude and simple water. But the greatest error they have committed, is in making their principles perishable and corruptible: for this they do when they introduce such a principle as quits and forsakes its nature in composition.* But we shall presently have occasion to press this argument farther, in speaking to the third kind of philosophers; who make several principles of things.

SECT. II.

THE PHILOSOPHY OF THOSE THAT MAINTAIN MORE THAN ONE PRINCIPLE OF ALL THINGS.

THE philosophers that maintain several principles of things, may seem to have more strength than the former: they certainly have more prejudice; and therefore we shall consider their opinions, not together in the lump, but each of them separate. We must observe the distinction al-

* Nam quodcunque suis mutatum finibus exit,
Continuo hoc mors est illius, quod fuit ante.

ready made, betwixt those who assert several principles, and those who make them infinite; the latter will come properly under the fable of Cœlum: at present we are concerned only with the former.

Among the ancients, Parmenides asserted two principles of things, viz. fire and earth, or heaven and earth: for he maintained that the sun and stars were pure limpid fire; not degenerate as it is with us, where it appears like Vulcan precipitated head-long from heaven to earth, and become lame with the fall. This doctrine of Parmenides has been renewed in our time by Telesius, a man well versed in Peripatetical reasonings; (if those were of any significance) so as to retort the arguments of that sect upon themselves: though he is entangled with his own positions; and seems better at pulling down, than at building up. We have only a very slender and scanty history of the discoveries of Parmenides: but the foundations of an opinion like his, are plainly laid in the book that Plutarch wrote of the Primum Frigidum: which seems taken from some other ancient treatise, extant at that time, but now lost: for it contains several things of greater subtilty and strength than are to be found in the original works of that author. And this perhaps it was, that gave Telesius the hint, and courage to lay hold of the

doctrine, and strenuously labour it in his own Essays upon the Nature of Things.

The positions of this sect run thus*. They assert, 1. that heat and cold are the first forms, or the first active beings, and therefore the primitive substances; and yet that they have an incorporeal existence, supported by a passive potential matter, that may give them a corporeal bulk, equally susceptible of both natures, though itself be actionless. 2. That light is a pullulation, or springing forth of dissipated heat, multiplied and become strong and sensible, by collection. 3. That rarity and density are but textures, and as it were the weavings of heat and cold; and that from this weaving or opening by heat, and contracting by cold, bodies have a disposition or indisposition to motion. 4. That therefore, there are four co-essential natures; viz. heat, light, rarity, and mobility; with their opposites, cold, darkness, density, and immobility. 5. That the seats of the former are in the heavens, the stars, and particularly in the sun;

* The author here proceeds to enumerate, in a candid manner, the particular doctrinal points, maintained by Telesius; which are exceeding numerous; but at present generally exploded: we have therefore singled out a few of the principal, for a taste, though these, no more than the rest, are supportable upon his principles.

but of the latter in the earth. 6. That the heavens having an absolute and entire heat, on account of their vastly rarified matter, are most violently hot, shining, thin and moveable; but that the earth, on the contrary, from its entire, or undiminished coldness and most concentrated matter, is extremely, cold, dark, dense, perfectly immoveable, and absolutely averse to motion, &c. &c. &c.

Such are the positions of Telesius, and perhaps also of Parmenides, with regard to the principles of things. And certainly they might appear more true, if there were no such thing as man in the world, or any mechanic arts to torture, vex, and work upon matter; or if the world was to be simply considered as a bare structure, with regard to nothing but itself. For this philosophy looks more like the philosophy of a shepherd, than of a naturalist; or more like that of a bare observer, than of an operator; and considers the world calmly, and at leisure; or as in a state of inactivity: whence it is tolerable, as a mere system; but treats the business of principles in a very negligent and unskilful manner. It also commits a great error in the way of a system; by making such a one as may seem eternal, without supposing a chaos; or any changes and revolutions in the great structure of things. For whatever philosophy thus fashions,

lays down, and establishes a system, without making it rise from a chaotic state, seems but light, or hypothetical; and indeed discovers a narrowness of mind. For whoever philosophizes according to sense, must assert the eternity of matter; and deny it to the world, such as it now appears: which is a point well observed by the wisdom of the earliest ages; and, what approaches near to it, the philosophy of Democritus. And the same is confirmed by the scripture account; the difference consisting principally in this, that the scripture ascribes the existence of matter to God; whereas the other accounts would make it self-existent. For there seem to be three particulars known by faith, with relation to this affair; viz. 1. That matter was created out of nothing; 2. That a system was produced by the omnipotent word; or that matter did not form itself out of chaos, into the structure we now see; and 3. That this structure before the fall, was the best that the matter at first created was capable of. But other philosophies reached not so far as any one of these points; their patrons having an abhorrence of a creation out of nothing; and conceiving the structure of the universe produced after many revolutions, essays, and endeavours of matter; whilst they did not concern themselves about ranging it in the best manner; as they make the

structure but perishable and variable. In these particulars, therefore, it were better to rest upon the foundations of faith: but more of this in the fable of Cœlum, to which it properly belongs.*

As to the principles of Telesius; he might have considerably improved his second, viz. that of cold; as he lays it down not for a privation of heat, but as an independent, active principle, the rival of heat. And as we desire to favour all the discoveries that can any way be made in nature; and would give to every one of them their due weight; he might have proceeded to shew the action of cold upon matter, as he has done that of heat, in the following manner. The seat of cold is fixed and immoveable, excellently corresponding to the variable and moveable structure of heat; as an anvil to the hammer: for if both principles were variable and changeable, they would have produced temporary or momentary bodies. So again, the immense regions of heat, which he places in the heavens, are somewhat ballanced by the compact nature of the terrestrial globe, and the bodies about it; as the thing to be considered is not space, but the matter contained in space. Add to this that the nature, the efficacy, and the degrees of cold

* See the Sapientia Veterum.

cannot be largely treated of, for want of opportunities of making experiments therewith, in order to arrive at certainty. For the coldness of the earth has no substitute, within the power of man, to make experiments with, corresponding to that of culinary fire, which is a kind of substitute for the sun, and manifests the nature of heat. As to the cold exhalations which arise in the winter from the surface of the earth, in the coldest regions, and diffuse themselves in the air; they are but a kind of warm baths, in comparison to the primum frigidum hid in the bowels of the earth; whence the utmost cold that falls under the senses, and within the power of mankind, may be esteemed no greater in degree, than that of the sun in the hottest countries, compared with the blast-heat of a furnace, &c. And in this manner might his other positions be improved.

But the great fault, both in Telesius and others, who constitute principles, is that they derive them from things which have no existence; so that it were greatly to be wished men would once, by common consent, agree to leave off this trifling; and not feign beings, where no beings are; or place principles where they find none; and thus avoid embracing a manifest contradiction. For abstract principles, and perishable principles, are no principles at all; whilst there is an unavoidable necessity for men, if they

will walk intelligibly, to have recourse to atoms; which are real, material, figurative, measurable things, capable of situation, resistance, appetite, motion, action and efficacy: remaining for ever unimpaired and undiminished, the same through all the destructions and changes of natural bodies. For as there are such varieties of corruptions in the larger bodies, there must necessarily be some central part, as it were, that remains unchangeable: and this central part must either be somewhat potential or extremely small. But it can be nothing potential; for the primitive potential essence cannot be like other things that are potential; which differ in acts from what they are in power; but it must necessarily be something abstracted, as being uncapable of all action, and yet retaining all power: whence it must consequently be some immutable and extremely small thing; unless any one will maintain that there are no principles at all; but that one thing is a principle to another; and that the law and order of change is constant and eternal; and that the essence of things is vague and mutable. And it would be better, expressly to assert something of this kind, than through a desire of maintaining an eternal principle, run into a greater inconvenience, and make that principle phantastical. For in the former case there seems to be some issue; as things would then change from one to another in a circle: but on the foot-

ing of phantastical principles, there is no end; whilst notional things, and the helps of the mind are held as material beings.

It comes still closer to the point, that there are four demonstrations, which singly confute the philosophy of Telesius, as to principles; and much more when they are united. The first is, that there are found some very powerful and extensive actions and effects in things, that can in nowise be attributed to heat and cold. The second is, that there are some natures, of which cold and heat are the effects and consequences, not by the excitation of a heat inherent in them, or the application of an adventitious heat; but wherein heat and cold are lodged and generated from their first existence: whence they fail on both sides, of being principles; as there is something that does not proceed from them; and as they themselves proceed from something else. Thirdly, that those things which have their origin from heat and cold, do yet proceed from them, not as from a proper and intimate cause; but only as from an effect and instrument. Fourthly and lastly, that his conjunction of his four connatural things, is perfectly disorderly and confused. And to each of these we propose to speak, in particular.

It may doubtless appear to some not worth the while to be so strenuous in subverting the philosophy of Telesius, which itself is neither fa-

mous nor received. We answer, that we are not above considering the more ordinary matters; but for Telesius himself, we have a good opinion of him as of a lover of truth; a man useful in promoting the sciences; and one whom we acknowledge a principal modern improver of certain doctrines. We are not however here concerned with him as Telesius, but only as he is a restorer of the philosophy of Parmenides; to which great reverence is due. But the chief reason of our prosecuting this subject at large, is to lay, upon the first occasion, such a foundation as may commodiously be transferred to the confutation of the other sects, which we hereafter propose to consider: so as to avoid the necessity of repeating the same things, again and again. For as the roots and fibres of different errors are strangely interwoven and entangled among one another, they may frequently be confuted with one and the same argument; as different as weeds are cut down by the same scythe.*

* When the author had entered a little into this particular confutation of the principles of Telesius, the discourse breaks off abruptly; so that it seems more agreeable to end it here. It should seem as if the present piece, had it been finished, was intended to make a part of the tables for exhibiting the ancient and modern philosophies.

PHYSICAL ESSAYS.

OF THE CORPUSCULAR PHILOSOPHY.

THE doctrine of Democritus, concerning atoms, is either true or useful in demonstration: for it is not easy to conceive in thought, or to express in words, the real subtilty of nature, such as we find it in things, without the supposition of atoms.

This word has two significations, not greatly differing from each other; being either taken for the ultimate division, and the smallest portion of matter; or else for a solid particle, without vacuity.

As to the first, these two positions may be safely laid down; 1. That there is a much more subtile division and comminution found in things, than what falls under the sight; and 2. That this division cannot be endless or continued, in infinitum. For a diligent observer will find much more subtile and fine parts in continued bodies, than in such as are separated and discontinued. Thus a little saffron will tinge a whole hogshead of water; so as to render it distinguishable, even by the sight, from pure water

and this diffusion of the saffron through the water, doubtless exceeds the subtilty and fineness of the most exquisite powder; as may manifestly appear from mixing, in another hogshead of water, a like quantity of the powder of Brazil wood, balaustines, or any other tinging body, provided it has not the like tenacity or clamminess with saffron; which disposes it to spread, open, and incorporate with liquors. It were therefore ridiculous to take atoms for those corpuscles, that appear in the rays of the sun: such corpuscles being but like fine dust: whereas, Democritus himself declares that for atoms, no man ever saw, or can see them. *

This subtile division of things appears much more surprizing in the case of odours; for as a little saffron may tinge a whole hogshead of water; so a very little civet will impregnate the air of a very large room with its odour, or even two or three rooms successively. And let no man here imagine that odours diffuse themselves like light, heat, or cold, without any communication of substance; since it is observable that odours will, for a considerable time, adhere to wood, metal, † and other solid bodies; and may thence be dislodged and cleansed away, by washing and rubbing. But in these and the like instances, no one of a sound judgment will pretend that the pracess ‡ is infinite; such kind of division or diffusion is restrained to certain spaces, and certain limits, or quantities, of matter; as evidently appears in the preceding examples. §

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* Perhaps microscopes cannot be so far improved as to render the original component parts of matter visible. Though this ought to be farther attempted.

† As we see in perfumed sword-blades, &c.

‡ Viz. Of tinging or impregnating.

§ Viz. Of saffron and civet.

As to the second sense of the word atoms, which supposes a vacuum, and defines an atom from the want of vacuity; Hero has bestowed laudable pains about it: denying a collective, and asserting an interspersed vacuity. For when he saw the constant connection of bodies; and that no space could be assign'd absolutely empty of matter; and, what makes more to the purpose, observing that heavy and ponderous bodies would be carried upwards; or even in a manner, deposit and violate their natures, rather than suffer an absolute divulsion from the bodies contiguous to them; he laid it down as certain, that nature abhorred any great or collective vacuum. On the other hand, when he found that the same matter of a body would contract, or condense itself; and again open or dilate; so as sometimes to possess and fill a larger, and sometimes a smaller space; he could not conceive how this ingress and egress of bodies in their places happens, without an interspersed vacuity; that should be less when the body is compressed, and greater when it is relaxed. For this contraction must, of necessity, arise, 1. either because vacuity is excluded (after the manner just now mentioned, in proportion to the condensation; or, 2. because some other lighter body, intermixed with the body condensed, is squeezed out; or, 3. because there is some certain natural condensation and rarefaction of bodies. *

As to the second cause, that of squeezing out a more rarified body: it seems inconclusive: for although sponges and the like porous bodies do contract when the air is squeezed out of them: yet it is manifest by numerous experiments, that the air itself is capable of great contraction. Shall we suppose then that the more subtile part of the air

* See the author's History of Condensation and Rarefaction, passim.

is squeezed out, and afterwards another portion of this part, and so on for ever? But it strongly opposes this opinion, that the more rarefied any body is, the greater contraction it will sustain; whereas the contrary should be true, if contraction happened by the expression of a more rarefied part. 2. As to the third way; that the same bodies, no otherwise changed, should yet have a greater or less degree of rarity or density; it seems to be a dogmatical position, depending upon an absurd unexplained supposition, as Aristotle's positions generally do. 3. the first way, therefore, which supposes a vacuum, remains as the justest.

If any one shall here object, that it seems strange, and almost incredible that there should be an interspersed vacuity; whereas matter is every where at hand: let him attentively consider the instances above produced, of water tinged with saffron, and air impregnated with odours; and he will easily perceive there can be no part of the water assigned, where there is not saffron; and yet it is plain, by comparing the saffron and the water together, before they are mixed, that the body of the water is immensely greater than the body of the saffron; and so of the air and the odour. And if this be the case between different bodies, much rather may it be allowed between body and vacuity.

But the speculation of Hero, who was only a mechanical man, yields to the speculation of the famous philosopher Democritus, in this, that Hero not finding a collective vacuum in the lower globe of the earth; thence directly denied its existence: for this is no reason why there should not be a collective vacuum in the regions of the ether, where, without doubt, there are great expansions and rarefactions. *

* See Sir Isaac Newton's Principia, passim.

Men should here be admonished, not to confound their imaginations, and give themselves up to uncertainties, in these and the like enquiries, by reason of the subtilty of nature: but to conceive that generals may as well be submitted to examination and calculation as particulars. Thus it is as easy to mention, or think of a thousand years, as a thousand moments; because those years consist but of moments. Nor again, let any one imagine that such enquiries as these are rather matters of speculation, than of real use, and conducive to work: for we find that all the philosophers and others, who were versed in experience and particulars, and have given any true dissection of nature, have always fallen upon these enquiries, though indeed with no great success. Nor is there any juster or stronger reason why the present philosophy remains barren of works, than this, that it catches at the subtilties of words, and vulgar notions; without pursuing, or determining to enquire into the subtilty of nature.*

OF THE SIMILARITY AND DISSIMILARITY OF ATOMS.

The doctrines and discoveries of Pythagoras were generally such as seem better fitted for founding a religious order, than for opening a school in philosophy: and the event confirmed it; for his discipline has prevailed and flourished more in the heresy of the Manichees, and the superstition of Mahomet, than among philosophers. His opinion, however, that the world consists of numbers, may

* For more upon this subject, consult the History of Condensation and Rarefaction; and the Sylva Sylvarum, passim. See also Mr. Boyle's several pieces relating to it.

be taken in such a sense, as to enter into the principles of nature: for there are, and may be, two opinions concerning atoms, or the seeds of things; the one that of Democritus which attributes dissimilarity, and by figure, situation, to atoms: the other, perhaps, that of Pythagoras, which would have them all to be perfectly equal and similar. For he who ascribes similarity to atoms, necessarily places all things in numbers; but he who allows of other properties, employs the primitive nature of separate atoms, besides the numbers or ways of their coming together.

The practical question corresponding to this speculation, and capable of determining the point, is that which Democritus himself proposes; viz. Whether every thing may be made out of all things? Which he believing impossible, asserted a diversity of atoms. But the question to us seems not well put; nor so as to press and determine the point in the preceding speculation; if it be understood of the immediate transmutation of bodies: but the proper question is this; Do not all things pass in a due course of circulations and intermediate changes? For no doubt but the seeds of things, though similar, after having thrown themselves into certain knots, or combinations, entirely put on the nature of dissimilar bodies; till those knots, or combinations, come to be dissolved again; insomuch that the nature and properties of compounds may be as great a hindrance to immediate transmutation, as the nature and properties of simple bodies.* But Democritus, though acute in discovering the principles of bodies, is dissimilar to himself, and unskilful in examining the principles of motions;

* This requires to be well considered, and, if possible, to be determined; in order to the working of changes in bodies; and producing physical effects.

which indeed was the common defect of all the ancient philosophers. And yet, possibly, this enquiry concerning the primitive state of the seeds or atoms of things, may be of the greatest utility; afford the supreme rule of action and power; and justly direct and govern both hopes and works. *

And from hence arises another enquiry, which though not so extensively useful as the former, comes closer to things and works. This enquiry regards the business of separation and alteration; so as to discover what is effected by separation, and what by other means. For it is an error familiar to the mind, and has been spread and confirmed by the philosophy of the chemists, to attribute those things to separation, which are the effect of something else. Thus, for example, when water flies off in vapour, it is easy to imagine, that the more subtile part of the water is here discharged, while the grosser remains behind; as in green wood, where one part goes off in flame and smoke, and another remains behind in ashes. And something of this kind might be suspected of water, in a less manifest degree, for though the whole body of the water may seem to evaporate and be consumed, yet some grosser parts, like ashes, may remain adhering to the vessel. But here the imagination is liable to be deceived: for it is certain, that the whole body of the water may fly off into the air; †

* For if we could discover the original or primary component particles of matter, so as clearly to discern their arrangements and composition, whereon the form or properties of different bodies depend; we might be enabled to separate and combine these atoms so, as, under due limitations and restrictions, to produce all the possible changes in matter.

† Supposing the water perfectly pure, or free from all terrestrial matter; though there is an experiment produced to shew that water

or if any thing should stick to the vessel, this may not proceed from a separation of the grosser parts; but, perhaps, is the same substance as that which evaporates, only condensed by coming in contact with the sides of the vessel. So we see that quicksilver becomes totally volatile with heat, and is recoverable again without loss. So again, in the oil of lamps, and the tallow of candles, the whole quantity of the fat body becomes volatile; without leaving any ashes: for soot is generated after the flame, not before it; and therefore appears to be the skeleton or carcase of the flame; and not the dregs of the oil or tallow.

And this may serve as an introduction in nature, to a confutation of the notion of Democritus, as to a diversity of atoms; but for the introduction in opinion, this is much easier, and almost spontaneous; because the common philosophy makes its fictitious matter indifferent, and susceptible of all forms.

OF THE VULGAR DIVISION OF MOTION.

The division of motion at present received in philosophy, seems but popular, and groundless; as distinguishing the thing only by its effects, without regarding the discovery of causes. For generation, corruption, augmentation, diminution, alteration, and local motion, are no more than the works and effects of motions; which arriving at any manifest change of things, subject to vulgar notice, they are then very unscientifically called by those names,

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repeated distillations, is convertible into earth. See Mr. Boyle upon the subject, and Boerhaave's Chemistry, under the chapter of Water.

For doubtless, the meaning is this; that when a body, by any kind of motion has acquired a new form, or laid aside an old one, so as to complete its period, or run its course; men agree to call it a motion of generation or corruption: but if the form still remains, and the body only acquires a new quality or dimension, this is called motion of increase or diminution. So again, when the bulk remains the same, whilst the quality, actions, and passions, are changed; this they call a motion of alteration: but if the form, the bulk, and quantity, remain the same, and nothing is altered but the place, this they term local motion.

Whoever considers these motions with accuracy and diligence, will find them no other than the measures of motions; or only periods, certain stages, and as it were tasks of motions; and not real differences: as expressing indeed the fact, or what is done; but scarce intimating at all how it was brought about. These expressions, therefore, are necessary in teaching; and accommodated to the methods of logic; but are extremely empty in respect of natural knowledge. For all these motions will appear compounded, recompounded, and variously combined, if we would skilfully enter the more simple operations of nature. For the principles, the fountains, the causes, and the forms of motions, that is, the appetites and passions of all kinds of matter, are required in philosophy. So likewise are the impressions or impulses of motions, their checks and reluctances, their courses and obstacles, their alterations and mixtures, their revolutions and concatenations, and in short, the universal process of motions. Warm disputes, probable reasonings, vague contemplations, and plausible opinions, are here of little service: but the business is by proper means, and a suitable helping of nature, to excite, restrain,

increase, remit, multiply, check, and stop any motion, in a body susceptible thereof; and hence either preserve, change or transform bodies, at pleasure.

And here such motions should principally be enquired after, as are simple, original, and fundamental; of which the rest consist: for it is certain, that as the more simple motions are discovered, the human power will be the more enlarged, or the less confined to the use of determinate expedients; and the greater command it will have in producing new works. And doubtless, as that immense variety of words in all languages is composed of a few simple letters; so all the actions and powers of things consist in a few different kinds of original and simple motions.* It would therefore be unworthy of mankind, to have so accurately sifted and discovered the minute differences of their own voice, and yet remain illiterate in the voice of nature; and like the first ages, before the invention of letters, understand none but compound sounds and words; without distinguishing the simple elements of speech, or the letters of the alphabet.+

OF MOTION, AND THE MOVING PRINCIPLES OF THINGS.

The operative philosopher must lay the stress of his enquiry upon the consideration and examination of motion;

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* See the Novum Organum, Part II. Sect. II. Aph. 48.

+ The author intended, upon this footing, to have drawn up an alphabet of nature, containing all the simple notions, abstract natures, the cardinal powers, summary motions, measures of motions, &c. but here is only a very imperfect fragment of it, published by Dr. Tenison.

but the lovers of controversy and dispute, may consider the unactive principles of things. We call those unactive principles, which shew, whereof things may be made and consist; but not the means and the ways whereby they may come together and unite. For it is not sufficient, or of any great significance to action, and the enlargement of the human power, to know whereof things are composed; without understanding the ways and means of producing changes and transformations. Thus, does it follow, that he who knows all the simple ingredients of Mithridate, can certainly make that compound? Or must he who has exact descriptions of the materials and utensils employed in the making of glass, sugar, cloth, &c. of necessity have the art of preparing and producing these commodities? And yet the speculations of men are principally employed in discovering and examining these dead principles of things: just as if any one should propose and determine to look into the anatomy of the dead carcass of nature; without enquiring into her faculties and powers, when alive and active.

But all the enquiry made into the moving principles of things is little more than transient: and indeed it is astonishing to see how loosely, and with what negligence, the greatest and most useful thing in all nature has been treated and examined. Thus, if we look a little into the philosophy on foot, we shall find it turning upon such questions as these: Can matter be excited by privation? Is matter formed according to ideas? Do similar particles come into aggregates? Are atoms fortuitously tumbled about in vacuo? Is there any amity and enmity in matter? Do the heavens and the earth make mutual impressions upon each other? Do the heavens hold correspondence by symbolizing qualities? Have the celestial bodies any influence? Are

there any sympathies and antipathies in things? Are there any occult specific virtues and properties? Is their any such thing as fate or necessity? &c. But can all these kinds of generals, which are nothing but phantoms that play about the surfaces of things, be serviceable to mankind; or enlarge our stock of knowledge and power? They may indeed distend, and swell the imagination; but can no way contribute to the production of works, the changing of bodies, or the governing of motions.

So likewise to argue, subtilize, and distinguish betwixt natural and violent motion, self-motion, and motion from without; the terms and appellations of motions, and the like, is not to grapple with nature, but catching at shadows. All matters of this kind, therefore, being dropt, or delivered over to vulgar and ordinary discourse, those appetites and inclinations of things should be discovered, from whence proceeds all that great variety of effects and changes in the works of nature and art: whilst men thus endeavour to bring nature, like Proteus, under constraint. And certainly, the kinds of motion, rightly discovered and distinguished, are the true shackles of Proteus: for just as motions, that is, incentives and restraints, are checked and eased, so is matter converted and transformed.

OF VIOLENT AND PROJECTILE MOTION.

VIOLENT motion, as it is called, or the motion of projectiles, is one of the most common of all motions; and yet there has been a strange and supine negligence, in not attending to and enquiring about it. This neglect has proved highly detrimental: for the motion itself is a thing of infi-

nite utility; particularly in the business of engines and machines, gunnery, and all mechanics; whereof it is, in a manner, the life and soul. There are many who fancy themselves to have finished this enquiry, by pronouncing the motion we speak of, to be violent; and distinguishing it from natural motion. It is indeed, the peculiar manner and conduct of Aristotle, and his school, to provide answers, and short verbal determinations; but not to adjust and settle things; they shew how a man may disentangle himself in dispute, either by affirming or denying; but not what judgment he ought to form in his own mind.

Others, with more attention, laying hold of this position, that two bodies cannot be in the same place a' once; will have it, that the more forcible one impels, and the weaker gives way; and that this yielding, if the force applied be small, continues no longer than the first impulse, in the way of protrusion: but if greater, that it continues for some time after the other body is removed, till it remits by degrees; as in throwing. And these again, according to another inveterate custom of the same school, catch at the first appearances of things, without troubling themselves much with the process, or issue; as if all beginnings drew every thing else after them: whence they break off their enquiries with a hasty and untimely impatience. For to say that bodies give way upon the first stroke, is something; but to the point, how, after the impelling body is removed, the motion should continue, they are silent; and have no clear conception.

Others again, with greater diligence and perseverance, observing that the force of the air, as in winds, &c. sometimes blows down trees and buildings; conceive, that the force attending and carrying projectiles after the first im-

pulse, is owing to the air collected, and rushing in behind the moving body; so as to impel it forwards, as a current drives a ship. And these indeed go through with the matter, and bring the consideration to a conclusion; though not with the requisite truth and justness.

The fact seems to be this. The principal motion resides in the parts of the projectile; but this motion, by reason of its subtilty, being imperceptible to the sight, men have carelessly overlooked it. But whoever considers the thing attentively will find, that all hard bodies are extremely impatient of pressure, and have, as it were, a very acute sense thereof; insomuch, that if ever so little driven from their natural figure, they with great velocity, endeavour to free themselves; and recover their former state. And in order to this, all the parts, beginning with the first that is struck, thus protrude and thrust one another, as if by an external force; whence there ensues a continued and intense, though invisible trepidation, vibration, and commotion of all the parts.* Thus we see glass, sugar, and the like brittle things, break not always in the part struck upon; but in others remote from that where the blow was given: which evidently demonstrates this communication of the motion of pressure to the remoter parts; which motion extending every way, and exerting its force all around, causes a separation in that part where, from the precedent disposition of the body, the union was least firm. Nor yet does this motion, though it runs through and disturbs every part of

* If this were the case, would not the projected body conceive some small degree of heat in the air? Yet it has not, perhaps, been satisfactorily shewn, that a bullet grows at all hot by being discharged from a cannon. But in the instance below, iron wire grows hot by bending. See the Novum Organum, Part II. Aph. 11, &c.

body, appear to the sight, but by the effect of breaking, or separating the continuity.

So again we see, if a piece of iron wire, a quill, or the like flexible and elastic body, be bent between the fingers, and let go again; the ends presently start back to their former situation: the cause of which motion is, manifestly, not in the parts of the body so bent; but in the middle, that sustained the force from which this motion relieves the body. And in this example it plainly appears, that the cause of motion, above derived from the impulse of the air, is plainly excluded; there being here no percussion to protrude the air. This is also farther manifest, from that obvious and common practice of squeezing a plumb-stone, whilst fresh and slippery; and thus shooting it from between the fingers: for here also compression performs the office of percussion. But the most evident effect of this motion is perceived in the perpetual rotations or revolutions of projectiles, flying in the air: for though they move continually forwards; yet they do it in spirals, or by rolling round, and moving forwards at the same time. And indeed this spiral motion being so rapid, and yet so obvious, or as it were familiar to things, makes us doubt a little, whether it may not depend upon a higher principle; though, perhaps, there is no other cause of the effect than that now offered: for the pressure of a body excites a powerful motion in its smallest parts, sufficient to make it endeavour to release and free itself every way; whence a projectile does not only fly strait forward, but every other way tries to free itself; and therefore revolves: for by both these means it does something towards its own relaxation or release.

And though in solids this action may appear somewhat secret and subtile; yet it is very evident and palpable in

softer bodies: for as wax, lead, &c. when struck with the hammer give way, not only forwards but side ways, and all round; in the same manner, hard resisting bodies fly forwards, both in a direct line, and circularly: for there is a correspondence between the substance of a yielding soft body, and the local yielding in a hard one. And the passion of a hard body, when it flies and gets away, is clearly understood from the change of figure produced upon a soft one.

We do not, however, deny but the air may have some considerable share in assisting, hindering, directing, and governing the principal motion thus excited. And this explanation of violent or mechanical motion, which has hitherto lain concealed, is a kind of fountain to mechanical works and practice.

OF THE CORRESPONDENCE BETWEEN SENSIBLE AND INSENSIBLE BODIES.

THERE is a great agreement betwixt the passions of sensible and insensible bodies; excepting only that the sensible bodies have a spirit. Thus the pupilla of the eye is compared to a looking-glass, or to water; as it receives and reflects the images of light, and visible objects, in the same manner therewith. So the organ of hearing has a conformity with the figure of a cave; which excellently reflects sound and the voice. Again, the sympathies or attractions of things inanimate, with their peculiar dreads and flights, or avoidances, correspond to grateful and disagreeable odours in animals. And for the business of taste and touch, it, on the one hand, expresses, like an interpreter,

all the violences; and on the other, all the grateful and friendly insinuations, and all the representations of the passions which can happen in bodies inanimate. For compressions, extensions, corrosions, separations, and the like, lie concealed in the process of lifeless bodies; and are not perceived till after the effect is manifest: but in animals they are all performed with a sensation of pain, according to the different kinds or characteristics of the violence; the spirit here suffering along with them all. And from this principle we may know whether any animal has another sensation, besides those observed; as also how many, and what kind of sensations there may be in all the species of animals. For from the passions of matter justly distinguished, will follow the number of sensations; provided there be suitable organs, accompanied with a spirit, to observe them.*

* This is a speculation of consequence, and may perhaps require a little illustration. The bodies of animals suffer in all respects like insensible bodies; that is, with respect to their matter and external appearance. Thus plants are wounded and wither, rot, and putrefy, like animals, living bodies, &c. But animals having a spirit and perception; or a sensation of pain or pleasure, corresponding to the action wrought upon them; they know what they feel by a mark that inanimate bodies have not: so that the effects wrought upon inanimate bodies being known, we may infer that animals have the same effects wrought upon them; and a set of sensations agreeable thereto; provided they have organs to perceive and take notice of them. See Novum Organum, Part II. Aph. 27.

OF APPARENT REST, CONSISTENCY, AND FLUIDITY.

THAT certain bodies should be at rest, or motionless, seems reasonable; if understood of their wholes; but if of their parts, it may mislead the judgment: for there is no such thing as simple and absolute rest, both in the parts and the wholes of bodies: but that which is thought to be rest, proceeds either from some impediment, restraint, or equipollency of motions. Thus, for example, in the gardener's watering-pot, which is struck full of holes at the bottom; if the orifice of the pot be closed, the water will not run out at the bottom holes. And this apparently proceeds from a retractive motion, and not from a quiescent nature; for the water still tends as much downwards, as if it were in actual motion: but as there is no other body to succeed at the top of the vessel, the water at the bottom is drawn back by the water at the top, and thus forcibly withheld.* For if a stronger man should hold down a weaker, so that with his utmost strength the weaker should not be able to stir; yet the motion of re-action is not the less, for its not prevailing: or for being bound down by a stronger motion.

And this distinction of false rest is proper to be made on many occasions; and affords great light in the enquiry about the nature of solidity and fluidity. For solids seem to remain quiet, and at rest, in their position; but liquids to move about, and be mixed together. Thus a column or statue cannot be raised of water; as it may of wood or

* This phenomenon is now explained by the air's pressure being cut off at the top; but still continuing at the bottom, so as to support the water.

stone: whence men are apt to imagine, that the upper parts of the water endeavour, by a natural motion to flow downwards; but do not allow the same as to upper parts of wood or stone. Yet the upper parts of wood have the same tendency downwards, as those of water; and this tendency would shew itself, were it not bound down and restrained by another tendency, that is prevailing; viz. by the appetite of continuity, or avoidance of separation; which is an appetite residing both in water and wood: only in wood it is stronger, and in water weaker, than the motion of gravity. And that fluids also have this motion is manifest: thus we see, in bubbles of water, the fluid throws itself into fine films, in the form of a hemisphere, to avoid separation, or discontinuance: and so again, in the droppings of spouts, the water, that it may continue one with the other water, stretches itself out into a fine thread, as long as any fluid follows from behind; but if water be wanting to supply the continuation, it then rolls itself up into spherical drops, the diameter whereof is much larger than that of the former thread. In like manner we see, that water difficultly suffers a subtile division of its parts; for it will not by its own natural weight, without concussion, run out at very fine holes or cracks. Whence it is certain, that fluids have an appetite of continuity, though it be weak.

But in solids this appetite is stronger, and over-rules the motion of gravity: for if any one imagines that the parts of a column of wood, or stone, have no tendency to fall downwards; but only to sustain themselves in the same state; he will easily be undeceived, by observing that such columns, if their altitude be not proportioned to the width of their basis, but run out beyond it, readily over-set, thro'

their too great weight a-top. And hence all high structures must necessarily rise in a pyramidal form, or grow narrower towards the top.

But what that nature is which increases and diminishes this appetite of continuity, is not easy to discover. It may perhaps be suggested, that the parts of solids are more dense and compact; and those of liquids more rare and loose; or that liquids contain air, which is a principle of fluidity not contained in solids; but neither of these seems agreeable to the truth. For it is manifest that snow and wax, which may be cut and wrought, and made to receive impressions, are much rarer than quicksilver, or melted lead; as is evident from the disproportion of their gravities. But it may be pretended, that perhaps snow or wax, though in their wholes they are rarer than quicksilver, yet contain parts more close and compact; only, being spungy bodies they have many cavities, and contain air; whence the total sum is lighter; as in the case of a pumice, which may perhaps be specifically lighter than wood; yet if both of them were pulverized, the powder of the pumice would be heavier than that of the powder of the wood; because the pumice now no longer retains its cavities. We allow this to be well objected: but what shall be said of melted snow and melted wax, where the cavities are filled up? or, what to gummy bodies, such as mastic, and the like, which have not those visible cavities; and yet prove lighter than numerous liquors?

As to the matter of air, the force and action whereof is supposed to cause fluidity; this at first sight seems probable, and familiar to mens' common notions; but in reality it is erroneous and somewhat hard to conceive; being not only destitute of a just reason, but almost opposite to rea-

son: for this pretended air really induces consistence, and not fluidity, as appears evidently in the instance of snow; which is a body compounded of water and air; each of them separately fluid; yet acquire a consistence by mixture. If it be here objected that this may happen from a condensation of the aqueous part of cold, and not from an interposition of the air; we have an instance to the contrary in froth, which is a body like to snow, and yet in no respect condensed by cold. If it be still urged that in froth the condensation proceeds not from cold, but from agitation and percussion; we may have recourse to that experiment of children, who by blowing gently through a pipe into soapy water, raise a tower or a structure of bubbles, one upon the top of another.

The case seems to be this; that bodies resolve and open themselves upon the contact of others similar or agreeable to them; but contract and shrink into themselves upon contact with dissimilar bodies: whence the apposition of a foreign body should seem the cause of consistence. Thus we see that oil and water mixed together, as in the making of unguents, put off their fluidity; and appear in some measure consistent: on the contrary, paper moistened with water resolves, and deposits its consistence, which before was strong, on account of the air intermixed in its pores; but does this less when moistened with oil; because oil has a less agreement with paper. And the like we find happens in sugar and bodies of that kind, which open themselves to receive water or wine: and this not only when such liquors are poured upon them; but they also attract and draw the liquor up into their substance, when no more than their lower part is dipped therein.

OF THE CAUSE OF THE MOTION OF EXPLOSION IN GUNS AND GUNPOWDER.

The phenomenon of gunpowder, and the cause of explosion, though so powerful and noble a motion, have been hitherto very imperfectly explained; and that too in the least considerable part. They pretend that gunpowder, when converted and rarified into flame, dilates itself, and possesses a larger space; from whence follows the explosion, or bursting of the obstructing body; lest otherwise two bodies should be in one place, or a penetration of dimensions ensue, or the form of the element be destroyed, or the situation of the parts of the resisting body become preternatural. There is something in this; for the appetite and passion of matter here mentioned, have some share in producing the effect: but the error lies in too hastily bringing the whole to a necessity of the body's dilating; without distinctly considering what precedes it in nature. For though it be necessary that the body of the powder, after it is converted into flame, should possess a greater space; yet it is not of the same necessity, that the body of the powder should take flame; and that with such rapidity: but this depends upon the preceding conflict, and a train of motions. For doubtless the solid and ponderous body, or bullet, discharged, makes a strong resistance before it yields; and if this resistance be great, it must needs prevail; so as that the flame shall not drive out the bullet; but the bullet stifle the flame. Therefore, if instead of gunpowder we were to use sulphur, camphire, or the like bodies, which also suddenly catch flame; and because compactness hinders inflammability, if these materials were formed into corns of

powder, with a proper proportion of the most combustible wood-coal; yet if nitre were not employed in the composition, there would follow no such rapid and powerful motion as in gunpowder: but the motion of inflammation would be checked, and kept down by the resistance of the bullet; and so the event be frustrated, or no explosion be made.

The case seems to be this. The motion here enquired after is double and compounded; for besides the motion of inflammation, which principally resides in the sulphur of the powder; there is another more strong and violent. This chiefly proceeds from the crude and aqueous spirit of the nitre; and somewhat again from the willow-coal. For this spirit is not only expanded, as vapours are by heat; but, what is here the principal thing, flies away and bursts forth, with the utmost violence, from the heat and inflammation; for which it thus opens and prepares the way. We see some resemblance of this motion in the crackling of dry bay, or ivy leaves, when thrown into the fire; and still more evidently in salt, which approaches nearer to the nature of the thing under consideration: we also find somewhat like it when the tallow of a burning candle happens to be wet;* and frequently in the flatulent flames of green wood. But a capital instance of this motion appears in quicksilver; which is an extremely crude body, and like a metallic water; the force whereof when close confined and excited by the fire; is little inferior to, or, perhaps, stronger than, that of gunpowder. From this example, therefore, men are to be admonished, and entreated not suddenly to

* Or more remarkably when cold water is thrown into boiling oil first set on fire.

seize upon any one thing in the enquiry after causes; and hastily pronounce from it; but to cast about, and fix their speculations deep and strong.

OF THE QUANTITY OF MATTER IN THE UNIVERSE.

It is evident that all things change; that nothing is truly lost; and that the total sum of matter remains perfectly the same, And as it was the work of Omnipotence to create something out of nothing; the same Omnipotence is required to reduce any thing back to nothing. Whether this be effected by a suspension of the conserving power, or by an act of dissolution, is not to the purpose; it is sufficient that it requires the decree of the Creator. But that men's thoughts upon this position may not be abstracted; or any fictitious matter introduced; we here advertise, that we conceive matter endowed with such a nature, that it may truly be said one body contains more, and another less thereof, in the same dimensions: for example, lead more than water, and air much less than water; and this not in an uncertain and indefinite, but precise proportion; so as to be exactly calculated and adjusted.* And therefore, if any one shall say that air may be made of water, and water of air; there is no absurdity in it: but if we should say that a certain measure of water may be converted into an equal measure of air; this is absurd; and the same as to say that something may be reduced to nothing. And in like manner, to say that a certain measure of air may be converted into the same measure of water; is to say,

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* See the History of Condensation and Rarifaction.

that something may be made out of nothing. And from these positions may be derived three precepts, or useful admonitions, directing men to a more skilful, and thence to a more useful correspondence with nature.

The first is this, that men should frequently call upon nature, to give in her account; that is, when they perceive a body, which was first manifest to the senses, to have flown away and disappear, they should not admit or clear her account, before they are made sensible whither the body is gone, or what it is received into. This matter at present seems treated with the utmost negligence; and men's contemplations about it generally end with sight; so that they do not know even where such a common thing as flame betakes itself: for to imagine it changed into the body of the air is absolutely erroneous.*

The second precept is, that men thus considering the unavoidable necessity there is in the nature of matter to support itself, without being dissolved, or falling into nothing; they should omit no way of torturing, and working upon matter; if they desire to discover and bring its ultimate operations and resistances to light. This direction indeed may seem not very artificial; but it is still of use. Thus in particular, we may observe that the greatest impediment men meet with either in working or experimenting, is this; that they find it scarce possible to preserve a certain mass of matter, without addition or diminution; whilst they would urge, press, and subdue it; but it eludes their ultimate force by division or separation. Now the separation that may happen here is of two kinds: for either part of the matter may fly off as in decoction; or at least there

* See the Sylva Sylvarum, under the article *Flame*.

may be a separation, as when cream rises upon milk. The design therefore of a deep and intimate change of bodies is to vex and torture the matter of them to the utmost, by the proper means; so as to prevent, if possible, these two separations: for it is then that matter will be really bound and manacled, when all ways of escape are blocked up or cut off.*

The third precept is, that when men see alterations may be made in bodies, without any increase or diminution of their bulk of matter, they would first purge their imaginations from this deep-rooted error, that alteration proceeds only from a separation of parts; and secondly, with skill and diligence, begin to distinguish betwixt alterations; and learn when they are owing to a separation, when only to a disorder or different situation of parts, without any separation; and when to both. Thus for example, when an austere and unripe pear is squeezed, bruised, rolled, or strongly wrought with the hand, and thence acquires a sweetness; or when amber or gums are reduced to fine powder, and lose their colour and beauty; it is not conceivable that any considerable portion of their substance should be wasted; but only the parts of the bodies brought into a new arrangement or order.

There is also another error to be extirpated, of such force, that, if it prevails, some of the particulars here intimated may be held as desperate: for it is a common opinion that the spirits of things, when raised or rarified by heat to a certain high degree of tenuity, will escape thro' the small pores of the most solid vessel, whether of silver, glass, &c. which is not true; for neither air, nor spirit,

* To this purpose see the History of Condensation and Rarifaction.

though rarified by heat, nor even flame itself readily becomes so fine, as to pass or make its way through such pores. Nor indeed would air sustain to be close confined and compressed, if it could any way perspire and get out at the pores of the containing vessel. Men, therefore, need not be so apprehensive that the spirits of bodies should easily escape them; especially since the spirits they frequently require, which are those of odours, tastes, and the like, may certainly be confined.

OF THE EBBING AND FLOWING OF THE SEA.

The causes of the ebbing and flowing of the sea were touched upon by the ancients; and afterwards dropt: but have again been renewed by the moderns; though with such a variety of opinions, as seem rather to confound the imagination, than discuss the point. Vulgar conjecture attributes this phenomenon to the moon; by reason of some correspondence between the tides and the moon's motion; but if we carefully examine the matter, there will appear some traces of truth, capable of leading us to greater certainty. To prevent confusion in this enquiry, the motions of the sea should be first distinguished; which, though considerably multiplied by some, are in fact no more than five: one whereof is irregular, and the others constant.

The first motion is that uncertain and various kind, called by the name of currents. The second is the great motion of the ocean, every six hours; by which the waters come up to the shores, and fall back again alternately, twice a day; though with such a difference as makes a revolution once in a month. The third, is the menstrual motion.

no other than a restoration of the diurnal motion, just now mentioned, to the same courses again. The fourth is the same menstrual motion, by which the tides have an increase at new and full moon, above what they have in the quarters. The fifth is the half-yearly motion; by which they rise remarkably higher in the equinoxes. But the second, or great diurnal motion of the ocean is the principal subject at present; and we shall only touch upon the rest in the way, as they may help to explain this capital one.

1. First, therefore, as to the motion of the currents; doubtless in the production hereof, the waters are either straitened by some narrow passages or channels; run free from some open places; or descend down a declivity; or ascend some eminence; or flow upon an even bottom; or meet with inequalities, rises and falls; or chop in with other currents, and mix and go along with them; or else are agitated by the winds, especially those that are anniversary, or stationary, and return at certain seasons of the year. And from these or the like causes, the waters may vary their tendency, and their eddies, as well in the consecution and progress of their motion, as in the velocity or measure of their motion; and thence constitute currents. It is therefore manifest that in the sea, the depth of the channel, the intervention of submarine rocks and caverns, the windings of the shores, the jutting out of promontories, the interposition of bays, gulphs, islands, and many other things variously situated, may act powerfully, affect the waters, and direct their courses, their windings, and their eddies, to all the points of the compass, according to the particular configuration and position of these accidental things, with regard to one another; or as such obstacles, declivities, or open passages happen in the way.

The consideration of this particular, and as it were fortuitous motion of the waters, must for the present be dropt; that it may not disturb the enquiry: for it would be wrong to reject what we shall offer about the natural and general motion of the ocean, because this motion of the currents does not agree, or conspire therewith. For currents are mere compressions of the water, or their endeavour to free themselves from compression; and are accordingly particular, respective, and conformable to certain situations of the sea and land; and to the winds that blow in particular places. And this is the rather to be remembered and observed, because the general motion of the ocean, now under enquiry, is so mild and gentle as to be perfectly subdued and made subservient to the force of the currents; and be governed and directed by their motion. That this is the case appears plainly from hence, that the simple motion of the flux and reflux of the sea is not perceived in the middle of the ocean; especially where the waters have a wide spread; but only at the shores. Whence it is no wonder it should lye concealed, and be in a manner destroyed by the currents, upon account of its feeble force; if where the currents have the direction, this motion did not somewhat add to their strength; and check them a little, where it is opposite or unfavourable.

Having thus excluded the motion of the currents, we proceed to those four constant motions; viz. the diurnal, the menstrual, the semi-menstrual, and the equinoctial motions; the former whereof alone seems to excite the flowing of the sea; whilst the menstrual motion appears only to determine and restore that motion, and the semi-menstrual and semi-annual, or equinoctial, motions only to swell and increase it: this original motion causing the flux and reflux of the

waters, which to a certain height overspread the sea-shores, and again forsake them, and return at different hours with a different force and quantity; whence those three other motions are made visible. This motion therefore, of the flux and reflux, must be treated separately; and in the peculiar manner it requires.

And first it must absolutely be allowed that this motion is either a motion of rising and falling; or a motion of progression in the waters. By a motion of rising and falling, we understand such an one as appears in boiling water; whilst it rises up and sinks down again: and by a motion of progression, such an one as we find in water moved in a bason: whilst forsaking one side, it rises on the other. That this motion is not of the first kind appears from hence, that the tides vary in point of time, in different parts of the world; so that whilst they flow in some places, they ebb in others at the same hours: whereas if the waters had no progressive motion, and moved not from one place to another, but swelled up from the depth of the sea; they would rise and sink in all places at the same time. Thus we see that the equinoctial and semi-menstrual motions have their effect and operation over the whole globe at once; for the tide of flood every where rises higher in the equinoctial and spring tides; but no where in the quarters. In these two latter motions, therefore, the waters seem perfectly to rise up and sink down again; or like the planets to have their apogees and perigees. But in the flux and reflux of the sea, we speak of, the case is quite contrary: which affords a certain sign of a progressive motion.

Besides, if this flux of the waters should be attributed to a bare swelling or rising; let us attentively consider how it must happen: for it must either proceed, 1. from an in-

crease of quantity in the waters; or, 2. from an extension, or rarifaction thereof, in the same quantity; or, 3. from a simple rising in the same quantity, and the same bulk or body. But the third case must absolutely be rejected: for if the water be raised up as it is, there must of necessity be a vacuum left between the earth and the bottom of the water; because there is no body of equal density to succeed in its place. And for the first case, if the quantity of the waters is increased, the additional part must necessarily spring or flow from the earth. But lastly, if there be an extension, this may happen either by rarifaction, or by an appetite of approaching some other body which attracts the water, and raises it up. And certainly this swelling, rarifaction, or tendency of the water to some of the celestial bodies, seems no incredible thing; if it be only in a moderate quantity: and a considerable space of time be allowed for such a swelling to collect and rise.* And therefore that excess of the waters observable betwixt the ordinary tides, and the spring-tides, or even those that are still larger, the equinoctial tides, being not equal to the difference betwixt the tide of flood, and the tide of ebb; and there being likewise a large compass of time allowed for the making of this gradual increase; the thing does not appear contrary to reason. But that so large a quantity of water, as the difference between the tide of flood, and the tide of ebb, should return so quick as every six hours, (whence Apollonius idly fancied the earth to draw in and discharge the waters in the

* As there is in Sir Isaac Newton's Theory: The action of the moon, not having its effect upon the water till three hours after she has passed the meridian.

way of respiration) is a phenomenon extremely difficult to account for.*

It may be objected, that certain springs are said to have a correspondence with the flux and reflux of the sea; whence it might be suspected, that the waters included in the caverns of the earth, rise and fall in the like manner: so that the tumefaction of the sea cannot well be attributed to a progressive motion. But this is a superficial instance: for it may easily be answered, that the tide of the sea coming in, may fill up many open and cavernous places of the earth; and thus turn the course of the subterraneous waters; and also drive back the air shut up in those places; so as by a continued succession to protrude and raise the waters of these springs. And hence, this is not the case in all springs, and indeed but in few; though it ought to be general, if the universal mass of waters had a nature and property of rising and sinking alternately; in conformity with the tides of the sea. But, on the contrary, this phenomenon is rare, and looked upon as extraordinary; because such passages and communications of springs with the sea, are seldom to be found, without some obstruction or impediment. And to this purpose it may be proper to observe, that in deep mines lying near the sea, the air is said to be rendered so thick as to endanger suffocation to the diggers, at the time of the flowing of the tide: from whence it might seem manifest, that the waters do not rise, where none are evi-

* Except from the attraction of the moon, which in her course constantly draws the waters into a spheroidical figure. See Sir Isaac Newton's Theory of the Tides, explained by Dr. Halley, in the Philosophical Transactions. Lowth. Abridgm. Vol. II. p. 285, 288.

dently perceived to do so; but only that the air is driven back by the tide coming in.

There is another instance produced of much greater weight; and highly deserving of an answer: for it has been carefully observed, that the sea ebbs and flows upon the coasts of Europe and Florida at the same time. But this objection will be clearly removed, by what we shall soon deliver as to the course and progress of the ocean. The sum of the matter amounts to this, that the waters of the Indian ocean being obstructed and straitened by the shores of the old world and the new, they are protruded down the Atlantic, from south to north: whence it is no wonder they should flow equally on both shores; as those waters do which are driven from the sea into the mouths and channels of rivers; where it is plain that the motion of the sea is progressive to the rivers; and yet overflows the opposite shores, at the same time. But we must here, according to our custom ingenuously confess, and admonish mankind to observe and remember, that if it shall be found by experience, that the tide comes in at the same time upon the shores of Peru and China, as it does on those of Europe and Florida; the notion of a progressive motion in the flux and reflux of the sea must be rejected.* For if the tide rises at the same time upon the opposite shores of the southern and Atlantic ocean, there are no other shores in the world, where the reflux corresponds at the same time. But judgment must be formed of this from experience; to which we assign it over: and in the mean time conceive, that were it known how the whole of this matter stood,

* See the Memoirs of the Royal Academy of Sciences at Paris. An. 1713.

over all the globe, we should find that in some parts there was such a flux at a certain hour, as there is a reflux in others.* At present, however, we must suppose for a progressive motion, in the ebbing and flowing of the sea.

We come next to enquire from what cause, and from what correspondence of things, this motion of the flux and reflux of the sea proceeds. For all the greater motions, when regular and constant, are not solitary, or single; but have others in the nature of things, whereto they correspond. And thus both the semi-menstrual and the menstrual motions of the tides, appear to coincide with the motion of the moon; and their equinoctial motion with the motion of the sun: and again the rising and falling of the waters, resembles the apogees and perigees of the planets. But we desire men would observe, that it does not presently follow that those things which correspond in course and period of time, or even in the manner of their motion, must be by nature subordinate to, or the cause of, one another. For we dare not proceed so far as to assert, that the motions of the sun, or moon, are the causes of the motions below, which correspond thereto; or that the sun and moon have a dominion or influence over these motions of the sea: though such kind of thoughts find an easy entrance into the minds of men; by reason of the veneration they pay to the celestial bodies. But in the semi-menstrual motion, it will, if rightly considered, appear a perfectly uncommon and

* A full and adequate History of the Tides, over all the globe, is not, perhaps, hitherto procured; though some considerable parts may seem to be executed. See the Philosophical Transactions, the French Memoirs, Rohault's Physics, Varenius's Geography, Newton's Principia, and Morhoff's Polyhistor; de Mari ejusque Fluxu & Refluxu. Tom. II. Part II. p. 362, &c.

strange kind of subjection, for the tides at the new and full moon to be the same, when the moon is different. And many other arguments might be produced to abolish all fanciful notions of such over-ruling powers; and rather lead up to the general passions and appetites of matter; and the primary structure of things; from whence these resemblances proceed: not as if one was governed by another; but because they both flow from the same origins, and concomitant causes.* Though it is still true that nature delights in correspondences; so that there is scarce any thing found single or solitary. Whence we ought to examine with what other motions this diurnal one of the tides agrees, or corresponds.

We may first enquire how this motion answers to that of the moon. And we do not find that it any way corresponds therteto; except in the menstrual revolution: for the motion of the tides every six hours, which is the subject of the present enquiry, in no respect coincides with the menstrual course. Nor again, is the flux of the sea observed to follow upon any phasis or alteration of the moon. For whether the moon be in her increase or wane; whether she be above or under the earth; whether she be elevated higher or lower, above the horizon; whether she be in the meridian, or elsewhere; the flux and reflux of the seat has no corre-

* Hence we should remember, that though the doctrine of gravity, or the hypothesis of the moon's attraction, along with that of the sun, may fully account for the phenomena of the tides; yet there may be a more general principle, which causes this correspondence. And it seems by no means well considered, that exact solutions of phenomena are no proofs that the real causes of the effect are discovered.

† This is understood of visible correspondence; for otherwise, the author allows that the tides may be caused by the attraction of the celestial bodies.

spondence with any of these phenomena. Therefore rejecting the correspondences of the moon, we must search for others.

Of all the celestial motions, the diurnal motion is the shortest; as being performed in the space of twenty-four hours: whence it seems most agreeable to refer the diurnal motion of the tides to this; as approaching the nearest: though there is still a difference between them, of three parts in four. But this does not press the matter. What has much more weight with us is, that this motion is so divided, as to answer the divisions of the diurnal motion of the heavens; so that though the motion of the waters is immensely slower than the diurnal motion of the heavens; it is yet commensurable with it; for six hours is a quarter of twenty-four, or a quarter of the measure of the diurnal motion; and this space is observed in the motion of the sea, with a difference coinciding with the measure of the moon's motion. And therefore we take it almost for certion, that the six hours' motion of the tides, is of the same kind with the apparent diurnal motion of the heavens.

Laying this down, therefore, as a foundation, we proceed with our enquiry; and conceive that the whole may be brought to an issue by prosecuting those three several questions; viz, First, Is the diurnal motion restrained to the confines of the heavens; or does it extend to the terrestrial bodies? Secondly, Does the ocean regularly move from east to west, as the heavens apparently do? And thirdly, Whence, and in what manner, proceeds the reciprocation of the tides, every six hours; corresponding to a quarter of the diurnal motion of the heavens; but with a difference coinciding with the moon's motion?

1. As to the first question; it should seem, that the re-

volving motion from east to west, is not a proper celestial, but a perfectly cosmical motion, and a primary one in the larger masses of fluids; possessing all the space from the highest heavens, to the lowest waters; but proceeding with very different degrees of velocity; though in the same direction: the velocity however diminishing, in a regular manner, the nearer the bodies approach to the globe of the earth.

And first, it seems a probable argument, that this motion does not terminate with the heavens, because it remains in force through all the immense space which lies betwixt the fixed stars, and the moon; a space infinitely larger than that betwixt the moon and the earth; though this motion decreases gradually all the way: whence it seems improbable, that nature should of a sudden, drop such a consent as had been continued and gradually remitted through such an immense tract. And that the case is thus in the celestial regions, may be argued from two inconveniences which would otherwise follow. For as it is manifest to the sense, that the planets have a diurnal motion; unless this motion be allowed natural, and proper, in all the planets, we must necessarily have recourse to the rapid revolution of the primum mobile; which seems entirely contrary to nature: or else to the rotation of the earth; which likewise is licentiously imagined, upon mathematical, and not upon physical reasons. Whence, probably, the case in the heavens should be as we have put it.

To leave the higher heavens; we have an evident instance of this motion in the lower comets, which descend below the moon, and yet revolve from east to west. For though they have their own particular and irregular motions, they still participate of the motion of the æther,

performing of those motions; and are carried in the same direction; though they are seldom confined within the zodiac; nor move in regular spirals, or in a figure compound of a strait line; and a circle; but sometimes run out towards the poles: yet these retain this rotatory motion from east to west; tho' greatly diminished by a nearer approach to the earth, and there revolving in lesser circles. This motion is, however, strong enough to carry them a very great distance in a short time: for these comets move round the whole circumference of at least the earth and atmosphere, in the space of twenty-four hours; with the anticipation of an hour or two.

But when, by a continued descent, this motion comes into those regions where the earth acts not only by a communication of its nature and virtue, which checks and deadens the circular motion; but also by the material emission of its own substance, in the form of gross vapours and exhalations; this motion is rendered prodigiously languid, and in a manner latent; though it be not totally destroyed. For in sailing between the tropics, where the sea is open, and the motion of the air is best perceived, and where the air itself revolves in larger circles, and consequently swifter; a constant breeze is found to blow from east to west: so that they who want a west-wind, are frequently obliged to procure it without the tropics. Hence it appears, that this rotatory motion is not lost, even in the lower air; only becomes sluggish and languid; so as scarce to be perceived out of the tropics. And yet even there too, in Europe, where the sea is calm, and the sky serene, sailors observe a certain breeze of the same kind, following the sun. And we have some reason to suspect, that what is observed in Europe, where the east wind is sharp and

drying, and the west wind more general and moist, does not wholly depend upon this, that the former with us blows from the continent, and the latter from the ocean; but also because, as the east wind blows in the same direction with the proper motion of the air, it accelerates and quickens that motion; and therefore dissipates and rarifies the air: whereas the west wind blowing in a direction contrary to that of the air's motion, drives the air back upon itself; and condenses it. Here also we might mention the common observation, that the high clouds generally move from east to west: whilst the winds near the earth blow in a contrary direction. And if this be not always the case, the reason may be, that there are sometimes contrary winds blowing, some above and others below: whilst the higher, if opposite, disturb the proper motion of the air. And thus much may serve to shew that the diurnal motion is not restrained to the confines of the heavens.*

2. The second question is, Whether the waters regularly and naturally move from east to west? By waters we here understand the collective mass of that fluid which makes such a large portion of nature, as to have a consent with the fabric and structure of the universe. And we judge that this mass of waters has the same kind of motion with the air, though in a less degree, and by reason of the grossness of the body not so manifest and apparent. We shall therefore, for the present, content ourselves with producing three eminent or prerogative instances† in confirmation of the fact. The first is, that there appears a manifest motion

* See the author's History of Winds, passim; and the Specimen of animated Astronomy.

† See the Novum Organum, Part II. Sect. II. passim.

and flux of the waters from the Indian Sea down to the Atlantic Ocean; and this in a stronger and swifter manner towards the Streights of Magellan, where there is an opening to the west; and another great one in the opposite part of the globe, from the Scythian to the British Sea. And these successions of waters evidently roll from east to west. And here we must particularly observe that in these two places only, the seas are open; and have an opportunity of describing an entire circle; whilst on the contrary, in the middle tracts of the globe, they are cut off, and straitened by two great obstacles; the old and the new world; and driven into the two channels of those twin oceans, the Southern, and Atlantic, as into the mouths of two rivers, stretching between the south and the north; which therefore does not affect the motion of succession from east to west. So that the true motion of the waters may be justly taken from those extremities of the globe above-mentioned, where they meet with no obstacle; but flow natural and unresisted. And this is our first prerogative instance.

Our second instance is this. Supposing the sea to flow at a certain hour in the mouth of the Streights of Gibraltar; it appears that the tide must come in slower at Cape St. Vincent than there; slower at the Land's-end, than at Cape St. Vincent; slower at King's-Island, than at the Land's-end; slower at the island Hechas than at King's-Island;* slower at the entrance of the British channel, than at Hechas; and slower on the coast of Normandy than at the entrance of the channel. Thus far is regular. But at

* Neither the island Hechas, nor King's-Island, appear in any of the maps that I have consulted, nor do I know what other names these islands go by.

Graveling the order becomes perfectly inverted; and proceeds with a great start; the tide coming in here nearly at the same time that it does at the Streight's mouth. And this second instance we join with the first: for as was just now said, we conceive that in the Indian ocean, and the Scythian sea; the waters have their natural course, from east to west, free, open, and uninterrupted; whereas their course is straitened, and rendered transverse in the channels of the Atlantic, and southern oceans; and also beat back by the shores which, on both sides, stretch along from north to south, and allow no free passage to the waters; except towards the extremities. But the protrusion of the waters caused by the Indian ocean to the north, and that on the opposite side, caused by the Scythian sea to the south, differ immensely in extent; by reason of the different force and quantity of the waters. The whole Atlantic, therefore, down to the British channel, obeys the impulse of the Indian ocean; whilst only the upper part of the Atlantic, which stretches towards Denmark and Norway, yields to the impulse of the Scythian sea. And this must necessarily be the case; because the great islands of the old and new world, have such a figure and extent, as widens to the north and sharpens to the south; whence, reciprocally, the seas to the south possess a greater, and those to the north a lesser space. And hence that vast mass of waters, which rolls from the Indian sea, and is turned into the Atlantic ocean, becomes able to protrude and drive down a course of waters, by a continued succession to the north, as it were into the British sea. But that much smaller quantity of water, which comes frem the Scythian sea, and has also, in a manner, a free passage, in its proper motion, to the west, along the coast of America, cannot turn the course of

the waters to the south, beyond the limits we have assigned, or the chops of the British channel. And in these opposite motions, there must necessarily be some limit; where they meet and conflict together; and where they must immediately change the order of farther procedure: and this happens about Graveling, as was above observed; this being the limit of the flux from the Indian and Scythian oceans. And that a certain irregularity of the tides should be found about Holland from these contrary fluxes, appears not only from the inverted order of the times of flood; but also by constant observation. And if this be the case, it must necessarily happen, that the more the parts and shores of the Atlantic ocean stretch to the south, and approach to the Indian ocean, the earlier the flux will happen in precedency; as proceeding from the proper motion of the Indian sea: and the more they extend to the north, up to the common limit where they are repelled by the opposite torrent of the Scythian sea, the later in consecution. And that this must be the case, plainly appears by the progress from the Streights of Gibraltar to the British Channel. Whence we conceive that the flux on the coast of Africa precedes, in point of time, that in the Streights; and conversly, that about Norway precedes that about Sweden · though we do not know this to be true from any history or observation.*

Our third instance is this. If the seas that are inclosed on one side, which we call bays, stretch in their direction from east to west, which is conspiring with the true motion of the waters, they have a strong and vigorous flux; but if they go in the opposite direction, their floods are languid

* See Philosoph. Transact. Abridgm. Vol. II. page 260, 296.

and obscure: for the Red-Sea has a large flux; and the Persian gulf, which runs more directly to the west, has a still larger: but the Mediterranean, which is the greatest bay of all, and the parts of it, the Euxine and Propontis, as likewise the Baltic; all which decline to the east; are almost without the tide of flood; or have it only in a feeble manner. But this difference appears most conspicuous in the parts of the Mediterranean; which so long as they tend to the east, or decline to the north, seem to lie at rest, without much tide; but after they turn to the west, as in the Adriatic sea, they have then again a remarkable flood. Add to this, that the small reflux found in the Mediterranean begins from the ocean; but the flux from the opposite side: so that the water rather follows the course from the east, than the return of the ocean. And only these three instances, we at present employ, with regard to the second question, or head of enquiry.

We might also offer another proof, agreeable to those already produced, but of an abstruser nature; and derive an argument for this motion of the waters, from east to west, not only from the consent of the heavens (as mentioned before;) where this motion is in its strength and vigour; but also from the earth, where it seems perfectly to cease: whence this motion might appear to be truly cosmical, and to affect all things, from the highest heavens down to the more internal parts of the earth. We mean, that the diurnal rotation is performed as we find it, from east to west, upon the proper poles of the north and south. For the diligence of Dr. Gilbert has discovered, that all earth, or what we call the terrestrial nature, being not a supple or soft, but a rigid, or, as he calls it, a robust thing; has a latent direction, or verticity, which manifests itself by nume-

rous exquisite experiments, in the direction of north and south. But we curb and correct this observation, so as to assert the fact only of the external concretions, near the surface of the earth; without continuing it down to the central parts: for, to make the earth a magnet, is a notion formed upon a slender foundation; it being impossible that the internal parts of the earth should be like any substance commonly seen; because all things, with us, are penetrated, relaxed, wrought upon, and fashioned by the sun, and the celestial bodies; so as in no respect to correspond with bodies having such a situation, as that the force of the sun and the other celestial influences and effects, cannot reach them. But the upper incrustations, or concretions, of the earth, seem to participate of the revolutions of the heavens, of the atmosphere, and of the waters; as far as consistent and figured bodies can have an agreement with such as are fluid and liquid; that is, not so as to revolve upon poles, but to have a direction and tendency towards them. For, as every globe, that turns upon a certain axis, without having a central motion, participates both of a moveable and a fixed nature; so, after the revolving power is checked, by a consistent or self-determining nature, yet the power and appetite of directing itself still remains, becomes augmented and united: insomuch that direction and verticity to poles in solid bodies, is the same thing as revolving upon poles in fluids.

3. The third and last question is this. Whence, and in what manner proceeds the reciprocation of the tides, every six hours, coinciding with a quarter of the diurnal motion, except the difference above-mentioned? In order to clear up this point, let us suppose the whole globe of the earth covered with water, as at the general deluge. In this case,

we conceive that the water, being now in one entire ball, and no way disturbed, would continually move forwards from east to west, every day for some certain space, though no great one; by reason of the remission and diminution of this motion, in the confines of the earth. Here, by the supposition, the earth would no way, by its interposition, hinder, or restrain, the free motion of the waters. Let us suppose again, the earth to be one single island, stretched out in length from north so south; which form and situation would greatly check and obstruct the water's motion, from east to west. In this case we conceive that the waters would proceed in their direct and natural course for a season; but that at length, being beat back by the island, they would return at equal distances, so as on this footing to make only one flux, and one reflux of the sea, in a day; at about the distance of twelve hours between them. Now suppose again, what is matter of fact, the earth divided into two islands, that of the old and that of the new world, (for the southern continent will, by reason of its situation, here give us no great disturbance, no more than Greenland or Nova Zembla) and that these two islands stretch almost over three zones of the world; and between which the Atlantic and the southern oceans take their courses; and that these oceans are no where open but towards the poles. On this supposition, we judge it must necessarily follow, that these two obstacles will introduce and communicate the nature of a double reciprocation to the whole body of the waters; and thus make the quarter of the diurnal motion; whilst the waters being bridled on both sides, a flux and reflux of the sea will happen twice a day, at the distance of six hours; as both the accession and the repercussion of the waters is double.

And if these two islands were like cylinders, or pillars, about which the waters throwed themselves, in equal dimensions, and strait shores, this motion would easily demonstrate itself to every one; though it now seems to be confounded and obscured, by so great a variety of position in the sea and land.

Nor is it difficult to form some conjecture, as to what degree of velocity may properly be attributed to this motion of the waters; and how far it may reach in a day. For if, in order to compute this velocity, we make choice of some certain shores, which are least mountainous or uneven, and are washed by a free ocean; and again, if the dimension of the dry land be taken betwixt the high-water and the low-water mark; and this distance be four times repeated; by reason of the four tides in a day; and the product of this number be again doubled, on account of the tides on the opposite shores of the same ocean; and some additional allowance be made to the product, for the perpendicular altitude of the shores, which always rise somewhat above the channel of the sea; this calculation will give the distance that a globe of water would move, in a day: provided it were free from all obstruction, and continually went forwards in a circular progression round the earth. And it is manifestly no great distance, that it would thus move in a day.

As to the difference which coincides with the moon's motion, and completes the menstrual period; we judge it to proceed from hence, that the space of six hours is not the exact measure of the reciprocation; as, in the same manner, the diurnal motion of none of the planets falls exactly within twenty-four hours; and that of the moon least of all; whence the measure of the flux and reflux of the sea

is not a quarter of the motion of the fixed stars, which is performed exactly in twenty-four hours; but a quarter of the moon's diurnal motion. *

PRECEPTS AND ADMONITIONS FOR THE BETTER PROSECUTING OF THIS ENQUIRY.

Before this matter can be fully and demonstratively settled, there are several lesser enquiries to be made; and in particular we recommend the following to future diligence.

1. Enquire whether the hour of flood about the coast of Afric precede the hour of flood about the Streights of Gibraltar; and in like manner whether the hour of flood about Norway, precede the hour of flood about Sweden; and whether this precede the hour of flood about Graveling.

2. Enquire whether the hour of flood about Brazil, precede the hour of flood on the coast of New Spain, and Florida.

3. Enquire whether the hour of flood on the coast of China, do not nearly coincide with the hour of flood on the coast of Peru; and again with the hour of ebb on the coasts of Africa and Forida.

4. Enquire how the hour of flood on the coast of Peru, differs from that on the coast of New Spain; and particularly how the differences of the hours of flood stand in both the shores of the isthmusses in America; and again

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* See Sir Isaac Newton's Theory of the Tides.

how the hour of flood on the coast of Peru, corresponds with that on the coast of China.

5. Enquire into the heights of the tides on different shores, as well as their times: for although high tides are generally caused by low shores; yet they still participate of the true motion of the sea; according as that proves favourable or opposite.

6. Enquire, particularly, into the state of the Caspian sea, which is a large collection of waters, excluded from a free communication with the ocean; to see if it has any flux or reflux; and in what manner they happen; for we conjecture that this sea may have a single, but not a double tide, in a day: whilst the water forsakes the eastern shore, and rises to the western of that sea.

7. Enquire whether the tides in the new and full moon, and in the equinoxes prove high, and large, in different parts of the world at once: not understanding by once, the same hour; for the hours differ according to the appulse of the waters to the shores; but on the same day.

8. For want of fuller information, this general enquiry of the ebbing and flowing of the sea, cannot be justly continued down to an explanation of the consent of the menstrual motion of the sea-tides with the motion of the moon; whether these motions proceed from a subordination to the moon; or, whether they both have one and the same cause: which should be farther examined.

9. The present enquiry is connected with that relating to the earth's diurnal motion; which should therefore be cleared up, before any thing is determined upon this head. For if the tides of the sea, be, as it were, the last extremity of the diurnal motion; it will follow that the globe

of the earth is fixed; or at least that its motion is much slower than the motion of the water. *

* This beginning of an enquiry about the cause of the tides, is a posthumous piece, that occurs among the Scripta published by Gruter and seems not intended to have come abroad, till, in the author's usual manner, it had been brought nearer to perfection. But imperfect as it is, it may deserve the place here assigned it, among other imperfect pieces, designedly wrote, not in the inductive, but ordinary manner.

APPENDIX.

HAD the two latter pieces been finished, according to the author's design; they would have contained, not only the best philosophy he was able to lay down, for the time; but also the rudiments of a much more perfect one, reserved for the sixth and last part of his great undertaking.

This double view of the author may seem to increase the difficulty of compleating a philosophy, whereof he has left us no more than a few sketches; without any explicit directions for conducting and bringing the whole to a period.

It appears, however, that this first philosophy was to be general, and copied after nature, in her full extent and latitude; so as to include the history of the heavens, of the earth, and of man: though the whole was intended only as an essay, or temporary structure, to be raised by the ordinary means; without the assistance of the art of induction: which art being afterwards employed upon it, was to afford fit matter for the second or perfect philosophy.

And if a tolerable first philosophy might have been wrote a century ago, when natural knowledge had been but little cultivated; doubtless such a philosophy may be wrote at present, to greater advantage; on account of the numerous experiments and observations that have of late been made in the several countries of Europe, for promoting all the parts of natural knowledge.

At least it cannot be unseasonable, for persons acquainted with the Lord Bacon's views, to try what may at present be done towards forming a first philosophy from the many portions of natural history that have been written since his time; beginning with those himself has left us, and descending gradually to the labours of later writers, and the works of several societies of Europe, instituted for the improvement of knowledge.

If a philosophy of this kind be supposed already extant, in the writings of M. Rohault, du Hamel, or other systematical authors; we must remember, what was before intimated, that the first philosophy of the Lord Bacon was to be general, and formed upon the model of the universe; and that it was to afford matter ready digested and prepared, as much as possibly it could be without the art of induction, for forming a second or more perfect axiomatical philosophy. In which light, the works of the above-mentioned philosophers, with others of the same kind, may, so far as they are found solid and serviceable, be received into this first philosophy as parts; but cannot be allowed to execute the whole.

Perhaps the end might be answered, in some considerable degree, by digesting into a proper order, the pure philosophical matters to be found in the writings of Dr. Hook, Mr. Boyle, Mr. Evelyn, Dr. Becher, M. Paschal, M. Mariotte, Dr. Stahl, and Sir Isaac Newton; in the Philosophi-

Transactions; the French Memoirs, the German Ephemerides, the Acta Eruditorum, &c. so as hence to form a kind of general system of philosophy; to be amended from time to time, as new improvements and discoveries shall be made. And unless something of this kind be done, it should seem that little advantage can be rationally expected from all the labour hitherto bestowed in collecting and registering such numbers of observations and experiments, as are to be met with in those writings.

An attempt in this way might also serve to shew the sufficiency or insufficiency of our present natural history; what progress has been made in the improvement of knowledge since the Lord Bacon's time; how far his directions have been followed; what is farther wanting towards compleating the design of his grand Instauration; and, in particular, how far we are prepared to enter upon the last part thereof, the Philosophia Secunda.

Again, a first philosophy of this kind might have a great tendency to promote the accomplishment of all the parts of the Instauration; and, consequently, the felicity of mankind; which is naturally founded in the perfection of philosophy. And, certainly, to procure such a first philosophy, upon this plan, were no difficult, or tedious task; if properly recommended to a competent number of hands.

But to execute the second or axiomatical philosophy, is a work of much greater labour, and length of time; for, to say the truth, the present state of knowledge seems by no means ripe enough to afford it, in any tolerable perfection; and perhaps some ages are still required to bring it to maturity. So that all we can do, at present, is to labour the under parts of this grand structure; and recommend the finishing of it to posterity.

We may, however, form some tolerable idea of this future philosophy; be convinced that it is within the human abilities to procure; and assured, that some considerable foundation is already laid for it. Thus much cannot well be doubted of by those who understand the nature and use of the author's Novum Organum, and his several portions of inductive history, to be met with in the Sylva Sylvarum, History of Life and Death, &c.

Nay, if men would in earnest bend their endeavours this way; and were possessed of a just and actuating notion of the thing intended; the work might be greatly shortened in point of time: but to possess mankind with a just notion of the thing, is no small part of the difficulty; and cannot be removed without some labour of thought on their own side. And, indeed, unless the Novum Organum be understood. and its force perceived and felt, there are little hopes of making the generality of men sensible of their own philosophical abilities.

This great work, therefore, must, of necessity, be conducted by those who understand the way of working with engines; where the strength of others may be advantageously employed, to an end which the labourers will not be easily apprized of.

The things wanting to perfect the design are; 1. A compleat inductive history; or a full set of enquiries into nature, with a direct view to the forming of philosophy, 2. The completion of the art of induction, or the execution of the whole design of the Novum Organum; 3. The due application of this art to the matter of inductive history; so as thence to deduce axioms of the highest order, for practice, contemplation, and human uses; 4. A collection of these axioms ranged in exact method; so as to form one single

systematical philosophy, in conformity with nature; and exhibit a true draught, or copy, of the universe, with all its laws; and 5. A short but full explanation, annexed to each axiom; so as to break it into parts, and bring it down to particular cases, both of theory and practice.

A philosophy procured in this manner is the ultimate end of the Instauration; an end worthy of the author; and fixed with true judgment, as a desirable, yet possible pitch of perfection; to which human knowledge may arrive, by a right use and application of the human faculties.

A little to exemplify and illustrate the method of raising such a philosophy; let us suppose. 1. A particular inductive history carefully wrote, or a rigorous enquiry made about the business of common fermentation; so as to register all the prerogative instances, capital facts and phænomena, or principal charges observed in the several subjects employed; as grapes, malt, treacle, sugar, &c. 2. That these instances being carefully ranged or tabled, and thoroughly considered, reduce themselves, by the method of rejection, or art of induction, to this single axiom; viz. That a saccharine matter is the basis of wines, beers, vinegars, and brandies. 3. This axiom would then be the result of the enquiry; and, like an algebraical expression, or general theorem, contain several arts wrapped up in few words. But, 4. To verify this axiom, and render it fit to be relied on, or worthy to enter the second philosophy; it must be verified by particular experiments. Thus, if a saccharine matter be the basis of wines, &c. let art try to obtain a sugar from all the substances that afford wines, &c. And 2. again, if a saccharine matter be the basis of wines, &c. let wines, &c. be made from sugar. The experiments therefore must be tried; and if sugar can be procured from all fermentable substances; if these substances will not afford wines, &c.

after the sugar is got out; and if wines, &c. can be made from sugar; the axiom may appear duly confirmed; or verified. 5. To draw out the several arts above-mentioned, and shew how they may all be hence improved or perfected, requires a particular explanation, under the several heads of wines, beers, vinegars, and brandies; or the arts of the wine-maker, wine-cooper, vintner, brewer, vinegar-maker, and distiller; each whereof may be improved, and some of them perfected by this discovery.

The axiom here set down is purposely made choice of, because it was the result of an enquiry, prosecuted with some diligence; and if the axiom be not absolutely perfect, yet it affords a highly useful physical canon: by means whereof many considerable things may be performed. And, doubtless, it would prove of great advantage to have a collection made of such axioms, which, though not perfectly true, or thoroughly verified, should yet hold in most cases, or rarely fail; and serve as useful guides, though not infallible. But then such axioms must always be the result of enquiries; and be found, not made: otherwise they are of no validity; and can never be trusted.

The example above proposed is taken from physics; but the same method of investigation is equally fitted for improving all the parts of knowledge; so that a civil policy, ethics, law, medicine, and the other branches of science, may be perfected in the same manner: whence it appears, that the Lord Bacon has thus opened a way for bringing philosophy to its highest perfection; and mankind to their greatest temporal happiness.

GLOSSARY;

OR,

EXPLANATION OF CERTAIN PHILOSOPHICAL TERMS, EITHER INVENTED, OR USED IN A NEW SENSE, BY THE AUTHOR.

ABSTRACTION.

THIS word the author frequently uses, to express the manner of forming notions; that is, not simple ideas, or sensations, which require no action or operation of the mind besides bare perception; but the manner of deducting, taking, or abstracting just notions from things, after a due consideration of all the particulars that should go to constitute such notions.

Thus notions hastily abstracted from things are faulty, slight, superficial and imperfect notions, derived from considering only a few obvious particulars; as the common notion of moisture is hastily abstracted or taken from considering only water: whereas such a philosophical notion of moisture should be formed, and introduced, as might

agree with all instances; viz. to quicksilver, which is moist in respect of gold; to oil, which is moist, in respect to leather; &c.

The due abstraction, therefore, or formation of notions, is a particular operation, or work, of the understanding; that requires the use of induction, in the author's sense thereof; which see, under the word *Induction*. And in this operation of the mind, the perfection of thought, language, and all philosophy principally consists.

ADVENTITIOUS.

By adventitious, or transcendental conditions of things the author understands the existence of things in a determinate, or certain quantity, under certain invariable differences; or to express it otherwise, the laws, or necessary causes in nature, whereby some things exist, and others do not; why there are such large quantities of some things, and less of others; why some things are possible, others impossible; and the like. Thus to enquire into the physical (not final) causes, why there is more iron than gold in the world; more marble than diamond; why it is impossible for men to preserve their own bodies in a sound state for ever; and the like; is enquiring into the adventitious, or transcendental conditions of things; and a neglected part of primary philosophy: which see.

ANTICIPATION.

By anticipation, the author, in a particular sense, understands the common method of reasoning, and judging of things with a kind of natural impatience, precipitancy, blind fury, and head-strong appetite; without a due regard to the real merits of the case; or without a proper regulation and government of the mind, by the use of his new machine, or logic. So that the method of anticipation is

directly opposite to his method of induction, or interpretation of nature: which see.

APHORISMS.

The author takes aphorisms in a somewhat stricter sense than the common; and means by them, not loose and scattered observations thrown together in a heap; but matter well weighed observation and experience, thoroughly digested in the mind, and afterwards clearly and methodically set down in writing; with a steady view to some useful end: without admitting any foreign ornament, superfluity, or exaggeration; but keeping close to the truth of nature, and reality.

APPROXIMATIONS.

By approximations the author understands such particulars as approach, or, in some degree, come up to optatives, or the desiderata in arts and sciences: so as, when these optatives, or desiderata, are for the present, impossible to be obtained; we may still have something of the same kind, within our power, tho' of an inferior degree. See *Optatives.*

ART OF INVENTING.

By the art of inventing arts is meant the use of a well regulated and perfect induction, applied to physics; being an art, or actual demonstration, as justly suited to this purpose, as algebra in mathematics: and may discover arts with as much certainty, as that can form equations. See *Induction,, Interpretation of Nature,* and *Investigation of Forms.* See also *Inductive History,* and *Learned Experience.*

ASSEMBLAGES.

By greater assemblages, or colleges, of matter, are understood the four elements, as they are commonly called; viz. fire, air, water, and earth: and by the smaller assembla-

ges, all the other natural bodies; as animals, plants and fossils.

ATTRACTION. See *Sympathy.*

AXIOMS.

By axioms the author does not mean mathematical axioms; or self-evident propositions; but a very different thing; viz. solid portions of truth, duly raised from enquiries conducted in the inductive method; or drawn, as rich corollaries, from particular histories of nature and art; so as to be pregnant with the matter of a just theory, and sure directions for practice. And these axioms can be no otherwise formed, than by a careful and accurate induction. In other words, a perfect axiom is a summary expression of the form, law, nature, or essence of a thing discovered after a due exclusion and rejection of every nature or property, that is not essential; so that the discovery of forms, and raising of perfect axioms are reciprocal, or one and the the same thing. See *Forms.* But besides these perfect axioms, there are others of an inferior nature, tending to raise up the more perfect by degrees.

CANONS.

Canons, in the author's particular sense of the word, are the same as axioms; unless we except that they more particularly regard practice; as axioms, if we make the difference, regard theory. The word canons is also sometimes used for useful observations of a general nature, or large extent.

CIVIL HISTORY.

By civil history is meant an account of the works and acts of men; as natural history is an account of the works and acts of nature.

CONFUTATION.

This word is used, not so much in a new sense, as applied in a new manner, or to a new purpose; viz. the confutation of demonstrations; the confutation of philosophies; and the confutation of the natural reason; which may seem harsh and strange expressions: but, as sophisms are confuted in the vulgar logic; so the author confutes the vulgar demonstrations, the vulgar philosophies, and the common method of reasoning, by shewing them all to be unfit for promoting the sciences; which require the use of perfect induction.

COSMICAL.

Cosmical motions, and cosmical qualities, are those motions and qualities which things have, as they are parts of the universe, or general system of nature; and would not have the same, if they were not parts of one great whole.

ELECTIONS.

By elections, with regard to a sound and serviceable astrology, is meant the choice of proper times, or seasons, for performing certain actions or operations; so as to procure the assistance of the celestial influences, when these may be serviceable. Elections, therefore, are one principal use of astrology, and predictions another.

EXCLUSION.

By the method of exclusion, or rejection, is meant the throwing out of an enquiry all the subjects that have not the nature sought; and belongs particularly to genuine induction, or the art of investigating forms; where it constantly makes a table by itself called the table of delineation, absence in approach, exclusion, or rejection.

The expression has also a lower, or more obvious signification, denoting the refusal, or non-admittance, of dubious

and uncertain particulars, or matters of slight observation and experience, into an enquiry, or any particular history of nature and art; as also the weeding of such histories, and throwing out such particulars.

FORMS.

By forms, the author understands those real appetites, powers, motions, or active laws of nature, by which all things exist, and have their effects. And to the discovery of these laws, his principal endeavours are directed; as to a thing that alone will constitute a just and universal theory, and direct to an extensive practice. So that his instauration, or scheme for rebuilding arts and sciences, and bringing them to their perfection, depends upon the discovery of forms; or the finding of natures convertible with any natures assigned, that shall limit, and restrain, and constitute the former. Thus by discovering the form of gold, we should learn what constitutes that metal, or gives it the specific differences which distinguish it from all other things; and, at the same time, obtain a rule for introducing that form, or the nature of gold, into silver, or any other body susceptible thereof. But these forms are not yet discovered; and can be investigated no other way than by the use and application of the art of induction; which, itself is not hitherto extant in all its parts. See *Induction*.

Besides this eminent sense of the word, it is also used, in a more common acceptation, for the figure, shape, fashion, or manner of things.

GENERATIONS.

Generations are the ordinary productions of nature, as distinguished from the extraordinary, or monstrous; which the author calls pretergenerations.

GEORGICS.

This expression of georgics is transferred from agriculture into ethics; so as to denote the art of cultivating, or improving the mind in moral virtue.

HISTORY.

By pure history, the author means a collection, or faithful and exact description of the works, facts, or appearances of nature, without meddling with their causes; which is a province that belongs to the interpreter of nature.

Narrative history is distinguished from inductive history; the former containing descriptions, or relating the facts and works of nature, with no view to the founding a just philosophy; which is the design of inductive history. See *Inductive* and *Natural History*.

IDOLS.

By idols of the mind are denoted the various kinds of false representations, imaginations, figments, and wrong notions, which men received from education, party, particular studies, &c. so as to distinguish these from true notions, which are duly abstracted, and represent things as they are. See *Abstraction*.

INDUCTION.

This word is used, not in the common, but a much more noble sense, by the author, to signify an art, of which he was the inventor. This art has a great resemblance with algebra; and is to the investigation of forms, what that is with regard to the forming of equations. It consists of several parts, and is extremely well suited to natural enquiries, and the discovery of new arts, and works; so that it may well be called a philosophical algebra, or the art of inventing arts; a considerable branch whereof, is delivered

in the author's piece called Novum Organum. See *Art of Inventing Arts.*

INDUCTIVE HISTORY.

Inductive, primary, or mother history, is a natural and experimental history, collected, not in the ordinary way of natural histories, for amusement, delight, or the sake of the direct matters themselves; but with a view to the building up a solid and serviceable philosophy. Inductive history, therefore, was a thing entirely wanting, till the author set some examples of it in his History of Winds, Life and Death, &c. wherein he uses his own art of induction. See *Induction.*

INDUCTIVE METHOD.

Inductive method, is the method laid down by the art of induction. See *Induction,* and *Forms.*

INSTANCES.

By instances, the author understands particulars, facts, observations, experiments, natural bodies, instruments or any thing fitted to afford light and information in enquiries. But as it were endless to pursue the infinity of things in particular enquiries, the author, under the doctrine of instances, has shewn which are prerogative; that is, which are of such a nature as that a few of them may do the office of many; and thus greatly shorten the business of enquiry.

INSTAURATION.

The instauration is the author's general scheme or plan, which he lays down for the improvement of knowledge. This scheme consists of six parts: viz. (1.) a survey of the present stock of knowledge; with an account of its deficiencies, and the ways of supplying them. (2.) A new art of induction, philosophical algebra, machine, or particular logic, for discovering arts, and interpreting nature. (3.)

The materials for inductive history. (4.) The inductive history itself. (5.) The best Philosophy that the Author could raise without the assistance of induction. And (6.) a genuine and sound philosophy raised by the art of induction.

INTERPRETATION.

What the author properly means by the interpretation of nature, is the exercise of the last part of his art of induction; when the interpreter having all his tables, and the requisite materials and helps before him, examines what is the result of any particular enquiry; so as at length to discover the form of the nature sought; find the causes of effects; and draw out the axioms that direct new experiments and works. It is therefore the business of the natural or rather inductive historian, to collect the matter or instances of an enquiry; range them into regular tables, &c: and the business of the interpreter of nature to examine and compare the whole, with a view to the investigation of forms, the discovery of causes, and the raising of axioms.

But besides this limited sense of the term interpretation of nature, it has another, more general, and denotes the sober, artificial, just and regular procedure of the mind in the discovery of truth, according to the patient and laborious method of induction: in which light it is opposed to the vulgar method of anticipation; which, when soberly considered appears a kind of frantic, deformed and unruly thing.

LEARNED EXPERIENCE.

By learned experience the author understands the art of experimenting, or the proper method of making and conducting experiments, so as that they shall afford light, or lead to some certain discoveries; and not remain casual

fluctuating things, tried in the way of amusement, or fruitless curiosity.

LITERARY HISTORY.

By literary history is meant the history of matters any way relating to learning, through all ages and over all the countries of the world.

MACHINE.

What this is, see explained under the term *Novum Organum.*

MAGIC.

The word Magic is used by the author in its ancient honourable sense; or rather in one still more sublime and noble, for that practical doctrine, or science, which, from a discovery of forms, may produce very great works and effects, in the way of over-ruling, or commanding the general laws of nature. But as forms are not hitherto discovered, natural magic, which depends thereon, has at present no place among the sciences. Otherwise as mechanics is to physics, so is magic to metaphysics, or the discovery of forms.

The Persian magic is a sublime kind of wisdom, or science, depending upon the discovery of the natural relations betwixt the parts of the universe; and more particularly as applied to find out what relations and conformities civil states, or the art of government, should bear to the regulation and government of the world.

MATHEMATICS.

Mathematics, in the strict sense, is that part of metaphysics (in the author's acceptation) which considers quantity; but is more advantageously made an appendage, or auxiliary branch of science, subservient to physics, metaphysics, mechanics, and magic.

MECHANICS.

Mechanics is of two kinds, empirical and rational. By empirical mechanics the author understands that general method of operating in arts, which has no dependance upon physics, and proceeds without any knowledge of causes. And by rational mechanics he understands that method of operating, which is accompanied with a knowledge of physical causes.

METAPHYSICS.

This word is used in a particular sense by the author, to denote that contemplative part of natural philosophy, which discovers forms, and final causes; so as to shorten the way to knowledge, set the human power at liberty, and find out the true ultimate causes of things. See *Physics*.

NATURAL HISTORY.

By natural history, the author understands a description of generations, prætergenerations, and arts; or all the productions of nature, as well the ordinary as extraordinary and monstrous; and also of experience, or human arts and inventions. See History.

NATURAL THEOLOGY.

See *Divine Philosophy*, under *Philosophy*.

NATURES.

The author makes frequent use of the word nature or natures, to express what we often mean by properties; but the term is still of greater extent, and more generally useful. Thus (1.) natures are the same as things; (2.) the nature enquired into, is the subject sought, or the object of enquiry; but (3.) to introduce a given nature, is to introduce the form, or essential properties, of one thing into another; so as to convert the one into the other. And

(4.) nature united, or summed up, is the discovery of the general law, uniformity, or unity of action, employed by nature, or rather, the author of nature, in the production of all natural works and effects.

NOVUM ORGANUM.

Novum Organum is not only the title of that piece, wherein the author describes his new logic, art of induction, philosophical algebra, or new machine for working with the understanding upon all subjects, to the greatest advantage; but also denotes the art itself, whereby, as by an engine or artificial help for the mind, men may perform incomparably more than by their own natural powers; and ordinary capacities be thus enabled to prosecute enquiries, and promote general knowledge, as effectually as men of genius: the method of working with this help being like the method of working with algebra; or rather with a general engine, or instrument, proportioned to the strength, and fitted to the use of all men.

OPTATIVES.

By optatives the author understands desiderata, or such particulars as might be wished for, in order to the accommodation of life, and the enlargement of arts; as for example, power over the weather, the longitude at sea, new mechanical motions, &c.

PERCEPTION.

By perception, applied to inanimate bodies, we are to understand the same passion, or suffering, as happens in animate bodies; excepting only the difference that depends upon the spirit in animals, or a want of the senses.

PHILOSOPHY.

By philosophy in general, the author understands all

knowledge, except revelation, or inspired theology; so that arts and sciences are but other words for philosophy.

Primary philosophy, in the general sense, denotes a kind of common science, or collection of neutral axioms, belonging indifferently to all the sciences; together with the doctrine of adventitious or transcendental conditions. See *Adventitious Conditions.*

By natural philosophy, the author understands philosophy applied to the things of nature (as distinguished from the doctrine of the deity, and the doctrine of man) so as to discover causes, and produce effects. See *Physics* and *Metaphysics.*

Divine philosophy, or natural theology, is a science formed in the mind of man, by means of the light of nature, and the contemplation of the works of God, and tends to confute atheism, and determine the laws of nature, but not to establish any religion.

Philosophia prima, has the same signification with primary philosophy; but in a more particular sense, denotes the author's intended imperfect philosophy, to be raised in the best manner possible, without the assistance of the art of induction; as his philosophia secunda was to have been a pure and perfect axiomatical or universal philosophy, raised by the art of induction.

PHYSICS.

By physics the author understands that contemplative part of natural philosophy, which discovers the efficient causes, and the composition, matter, and structure of things; as metaphysics discover their forms and ends. Physics, therefore, and metaphysics, are the two contemplative, or theoretical parts of natural philosophy; of which answer the two practical ones of mechanics and magic.

By physics of creatures, or concrete physics, we are to understand that part of physics, which exhibits the varieties and lesser assemblages, or collections of things, pursued in the concretes or bodies themselves; and this part borders upon natural history.

Physics of natures, or abstract physics, is the same part pursued, not in concretes, or individuals, but in their accidents or qualities, so as to approach the nature of metaphysics.

PNEUMATICAL BODIES.

By pneumatical bodies the author means such as make no sensible resistance to the touch, or are not perceived, or found ponderous upon the balance in the open air.

PRÆTERGENERATIONS.

For the meaning of this word, see *Generations*.

PRIMARY HISTORY.

See *Inductive History*.

PRIMARY PHILOSOPHY.

See *Philosophy*.

PROFESSORIAL.

By professorial learning, and professorial arts and sciences, the author understands the arts and sciences, as taught in the common schools and universities; where he judges the arts are not much improved, but only retailed out in a sophistical manner, or dressed, adorned, and fashioned into systems, that are apt to deceive by their beautiful appearance.

PROMPTUARY.

By promptuary method is meant the procuring a fund of matter for discourse, by laying up, for use, arguments ready composed, with regard to such subjects as frequently occur.

REASON.

By reason the author frequently understands the rash and imprudent use of the rational faculty in philosophical subjects, so as presently to come at some erroneous conclusion, and proceed upon it as if it were true; without inuring this faculty to the same laborious search, suspension, and scrupulousness in philosophy, as is practised in mathematical demonstrations. See *Confutation*.

REDUCTION.

By reduction the author understands a proper contrivance, or artificial means, for bringing those things under the judgment of the senses which naturally escape them: or means of strengthening, assisting, and improving the senses; as by telescopes, microscopes, speaking-trumpets, ear-trumpets, &c.

REJECTION.

See *Exclusion*.

SCALA INTELLECTUS.

By scala intellectus the author understands the proper application of the art of induction, to the more interesting and important subjects of philosophy; so as duly to prosecute a set of capital enquiries, that shall lead, by degrees, to the most sublime, noble, and general axioms, pregnant with doctrine and directions for forming a just theory of nature, and the perfecting of arts.

SPIRIT.

By the spirit in bodies the author means a more subtile and rarified matter, of the same nature with the bodies themselves, residing in all their tangible parts, multiplying itself, or, as it were, feeding upon them; but, unless hindered, continually flying off into the air, so as in time to waste, exhaust, and consume the bodies.

SUBSTITUTION.

By substitution we are to understand the means of substituting, or using one object for another, where the senses fail us; and where instruments for helping, or improving the senses, are of no service. Thus, though we cannot directly examine flame, we may sometimes advantageously substitute its pabulum, or the matter whereof it consists, viz. oil, or spirit of wine, &c.

SYLVA SYLVARUM.

By sylva sylvarum is understood, as its name implies, a wood of experiments and observations; or a collection of materials, ready procured, and laid up for forming particular histories of nature and art, in the author's inductive manner.

SYMPATHY.

By sympathy, consent, attraction, &c. we are to understand, not any imaginary powers, but real appetites, or laws of motion or nature, found in certain things, whereby they have a tendency towards, or operate upon, one another at a distance.

TABLES.

By tables we are to understand sets of papers, containing each its separate matter, or particular instances, experiments, observations, &c. for filling up the heads of any enquiry, and working upon any subject, in the method of induction, so as no way to trust or burthen the memory or confound the understanding, but proceed as in algebraical operations, or as with a certain machine, or well-adapted mechanical contrivance for the purpose. See the article *Novum Organum*.

TOPICAL INVENTION.

By topical invention we are to understand a new me-

thod, depending upon a mixture of logic and philosophy, of setting down the principal heads, or leading particulars, of an enquiry, so as that the whole may be prosecuted to the best advantage, both with regard to the operation of the mind, and the discovery of the thing sought.

TRADITIVE.

By traditive doctrine, we are to understand all the arts relating to words and discourse, as grammar, hieroglyphics, writing, cypher, &c.

By traditive lamp, the author denotes a new method of teaching, or a scientifical, initiative, leading, and improveable manner of delivering down the sciences to posterity, instead of the doctrinal or dogmatical method in use.

By traditive prudence, the author understands the doctrine of method in speech.

TRANSCENDENTAL.

See *Adventitious Conditions.*

UNION AND UNITY OF NATURE.

See *Nature.*

WORKS.

By works the author understands considerable acts of the human power, or masteries over nature, so as by solid and rational means to subdue and bend her to the more useful purposes; as in lengthening the common period of life, making the wind do the office of animal strength, governing the weather, with all other things of the like useful kind, in respect to the accommodation of life.

N. B. The design of this Glossary is not to give exact definitions of the author's philosophical terms, but only some general notions of them, to prevent any misconstruction, and facilitate the understanding of his works. In

which view, it might not be amiss for those unacquainted with the author, to go over the Glossary once or twice, before the whole work is begun to be read: for as he had different views, with regard to the improvement of philosophy, from any of his predecessors, he was under a necessity of coining new terms, where none were extant to express his meaning. But when words had already been applied, in a sense approaching to that he intended, he uses them in a guarded manner, so as to express no other than actions, facts, phænomena, or realities, as they are found in nature: and under this restriction we are to understand the words Antipathy, Attraction, Fuga Vacui, Motion of Connexion, Sympathy, &c.

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